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VOLUME XX, 1927

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CONTENTS OF VOLUME XX.

CONTENTS OF NUMBER 1.

HOOD, J. DOUGLAS, AND WILLIAMS, C. B.—A Synopsis of the Thysanopterous Family Urothripidæ 1
PARKER, H. L., AND THOMPSON, W. R.—A Contribution to the Study of Hibernation in the Larva of the European Corn Borer (Pyrausta Nubilalis Hubn.) 10
ROGERS, J. SPEED—Notes on the Life History, Distribution and Ecology of Diotrepha Mirabilis Osten Sacken 23
LARSON, A. O.—The Host-Selection Principle as Applied to Bruchus Quadrimaculatus Fab 37
COTTON, R. T.—Notes on the Biology of the Meal Worms, Tenebrio Molitor Linne and T. Obscurus Fab 81
GLASGOW, Robert D.—Another Intermediary Insect Host of the Giant Thorn-Headed Worm of Swine 86
KENNEDY, CLARENCE HAMILTON—Some Non-Nervous Factors that Condition the Sensitivity of Insects to Moisture, Temperature, Light and Odors 87
NEEDHAM JAMES G.—The Rocky Mountain Species of the Mayfly Genus Ephemerella 107
ABBOTT, C. E.—The Effect of Monochromatic Light on Formica Dakotensis Specularis (Emery) 117
VAN DUZEE, M. C.—North American Species of Polymedon (Diptera Dolichopodidæ) 123
GLASGOW, ROBERT D.—Another Insect Vector of the Giant Thorn-Headed Worm of Swine 127
DAVIS, J. J.—Proceedings of the Twenty-first Annual Meeting 131

CONTENTS OF NUMBER 2.

MARSHALL, WM. S.—The Malpighian Tubules of the Larva of Heptagenia Interpunctata, Say 149
FRISON, THEODORE H.—The Development of the Castes of Bumblebees (Bremidæ: Hym.) 156
PLATH, O. E.—Notes on the Hibernation of Several North American Bumblebees 181
HAYES, WM. P.—The Immature Stages and Larval Anatomy of Anomala Kansana H. and McC. (Scarabaeidæ, Coleop.) 193
ABBOTT, C. E.—Experimental Data on the Olfactory Sense of Coleoptera, With Special Reference to the Necrophori 207
FROST, S. W.—Three New Species of Phytomyza (Agromyzidæ, Diptera) 217
LANGSTON, J. M.—A New Species of Phyllophaga From Mississippi 221
KNIGHT, HARRY H.—Megalopsallus, a New Genus of Miridæ With Five New Species From North America (Hemiptera) 224
KNOWLTON, GEORGE F.—A New Rabbit Brush Aphid From Utah 229
LAWSON, PAUL B.—New Species of Acinopterus (Homoptera, Cicadellidæ) 232
RANDOLPH, VANCE—On the Seasonal Migrations of Dione Vanillæ in Kansas 242
EWING, H. E.—The Hippoboscid Fly, Ornithomyia Avicularia Linnaeus, as a Carrier of Mallophaga 245
HINDS, W. E.—Notes on the Biology and Habits of the Peruvian Cotton Square Weevil (Anthonomus Vestitus Bohm.) 251
CUTRIGHT, C. R.—Notes on the Computing of Mean Temperatures for Biological Use 255
HUNGERFORD, H. B.—A New Species of Hydrometra From North America 262
BATCHELDER, C. H.—The Variability of Aphis Gossypii 263

264027

CONTENTS OF NUMBER 3.

MYERS, J. G.—Ethological Observations on Some Pyrrhocoridæ of Cuba..... 279
ALEXANDER, CHARLES P.—Studies on the Crane-Flies of Mexico. Part III. (Order Diptera, Superfamily Tipuloidea)..... 301
GLASER, R. W.—Studies on the Polyhedral Diseases of Insects Due to Filterable Viruses..... 319
GILLETTE, C. P.—Notes on a Few Aphid Species and the Genus Illinoia Wilson. 344
HOKE, GLADYS—Some Undescribed Diaspines From Mississippi..... 349
DAVIS, A. C.—Ciliated Epithelium in the Insecta..... 359
HATCH, MELVILLE H.—Concerning Melandryidæ (Coleoptera)..... 363
HATCH, MELVILLE H.—New Aberrations of Temnopsophus and Pseudebaeus (Malachiinæ, Coleoptera)..... 366
DECOURSEY, R. M.—A Bionomical Study of the Cluster Fly Pollenia Rudis (Fab.). (Diptera, Calliphoridæ)..... 368
BYERS, C. FRANCIS—Enallagma and Telagrion From Western Florida, With a Description of a New Species..... 385
COCKERELL, T. D. A.—Some North and South American Bees..... 393
SMITH, M. R.—A Contribution to the Biology and Distribution of One of the Legionary Ants, Eciton Schmitti Emery..... 401
VANCE, ARLO M.—On the Biology of Some Ichneumonids of the Genus Paniscus Schrk..... 405

CONTENTS OF NUMBER 4.

Symposium—Needed Lines of Investigation in American Entomology..... 419
Introduction—E. D. Ball, 419; Taxonomy—S. A. Rohwer, 423; Physiology—P. S. Welch, 429; Insect Bionomics—R. W. Doane, 436; Insect Ecology—W. C. Allee, 439; Beneficial Insects—L. O. Howard, 445; Economic Entomology—E. O. Essig, 451; Insect Control—W. P. Flint, 454; Summary—E. F. Phillips, 457.
CLAUSEN, C. P.—The Bionomics of Anastatus albitarsis Ashm. Parasitic in the eggs of Dictyoploca japonica Moore (Hymen)..... 461
FORBES, W. T. M.—The American Catopsilias (Lepidoptera Pieridæ)..... 474
BIRD, R. D.—The External Anatomy of the Larva of Hoplocampa halcyon Nort., with a Key to the Instars and to those of Related Species (Tenthredinidæ, Hymenoptera)..... 481
BALL, E. D., AND REEVES J. A.—Further Studies on the Genus Gypona and its Allies (Rhynchota Homoptera)..... 488
FINK, D. E.—The Application of Studies in Hydrogen Ion Concentration to Entomological Research..... 503
ROBINSON, WM.—The Thermocouple Method of Determining Temperatures.. 513
BEAL, J. A.—The Development of the Proventriculus of Pytyogenes hopkinsi Swaine..... 522
REED, HELEN—Some Observations on the Leaf-mining Flea-Beetle Dibolia borealis Chevrolat..... 540
ABBOTT, C. E.—Further Observations on the Olfactory Powers of the Necrophori..... 550
GRISWOLD, GRACE H.—The Development of Coccophagus Gossypariæ Gahan, a Parasite of the European Elm Scale..... 553
INDEX TO VOLUME XX..... 555

DATES OF ISSUE FOR VOLUME XX

March Number Issued April 22, 1927.
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December Number Issued December 30, 1927.

Stephanothrips occidentalis H. & W.

(The colors are of the species when seen by transmitted light. By reflected light the sub-hypodermal pigmentation is maroon red as stated in description.)

ANNALS
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Volume XX MARCH, 1927 Number 1

A SYNOPSIS OF THE THYSANOPTEROUS FAMILY UROTHRIPIDÆ.

J. Douglas Hood,
University of Rochester,
and
C. B. Williams,
Entomologist, Ministry of Agriculture, Cairo, Egypt.

The primary purpose of this paper is to describe more fully than was then possible, and to illustrate, the two new Urothripidæ made known in a preliminary way by the authors in Psyche, Vol. XXXII, 1925, pp. 68 and 69. At the same time it has been found convenient to include brief keys to the known genera and species of the family.

The Urothripidæ are one of the most specialized and aberrant families of the Thysanoptera, and for these reasons a group of more than usual interest to the student. Their pale coloration and lack of wings gives them a larviform appearance; and their great rarity in collections is possibly due more to their having been overlooked or neglected by collectors and to the obscure situations in which they live than to an actual scarity in nature. However that may be, only twenty-eight adult specimens have been recorded in the literature; and these have more frequently been taken under dead leaves than in any other habitat.

Historically our knowledge of the group is recent. The first representatives of the family, two species belonging to different genera, were described by Buffa in January, 1909, from specimens taken in Italy. Later in the same year Bagnall based a third genus and species on two specimens from German

264027

East Africa, and erected for the group the new family Urothripidæ. Mr. Bagnall's study of the two specimens known to him led him to ascribe to the group eleven spiracular openings instead of the typical number, four, found throughout the order; and three years later this character was used by him as the principal reason for the elevation of the Urothripidæ to subordinal rank, the name Polystigmata being given them in reference to the supposed supernumerary spiracles. Later in the year, Trybom, at the time of his description of still another genus and two new species, both from Natal, stated that the so-called stigmata observed by Bagnall were equally visible from both the dorsal and ventral surfaces and in his opinion not true stigmata at all. Concurring in Trybom's opinion, Hood, in 1915, placed the Suborder Polystigmata as a synonym of the Suborder Tubulifera and divided the latter into two new superfamilies, the Phlœothripoidea and the Urothripoidea. Since that date nothing of importance concerning the group was brought to the fore until the present authors, in April, 1925, extended the known geographical range of the group by describing from the New World a new genus and two new species taken nearly ten years previously by Mr. Williams in the West Indies and South America. The number of known genera is thus five, and the number of species seven, distributed in the Palæarctic, Ethopian, and Neotropical regions; but of course many more species await discovery.

Superfamily UROTHRIPOIDEA Hood.

1912. (April 13). ["A new suborder"] Hood, Proc. Biol. Soc. Washington, Vol. XXV, p. 64.
1912. (August). [Suborder] *Polystigmata* Bagnall, Ann. Mag. Nat. Hist., Ser. 8, Vol. X, p. 220.
1915. *Urothripoidea* Hood, Proc. Biol. Soc. Wash., Vol. XXVIII, p. 59.

Body decidedly roughened above; all known species wingless. [Maxillary palpi *two*-segmented, but basal segment very short]. Antennæ four- to seven-segmented. Hind coxæ more widely separated than fore and middle pairs. Female without ovipositor, the terminal segment of both sexes continuous beneath and tubular; ninth abdominal segment longer than eighth; terminal abdominal hairs very much longer than tube.

Embraces the following family, only.

Family UROTHRIPIDÆ Bagnall.

1909. *Urothripidæ* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 126.
1910. *Urothripidæ* Bagnall, Fauna Hawaiiensis, Vol. III, Pt. VI, p. 677.
1911. *Urothripidæ* Bagnall, Ier Cong. Int. d'Ent., p. 283.
1912. *Urothripidæ* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 31.
1915. *Urothripidæ* Hood, Proc. Biol. Soc. Wash., Vol. XXVIII, pp. 54, 59.

Five genera and seven species, all recent, known from the Palæarctic, Ethiopian, and Neotropical faunal realms.

Key to Genera.

I. Antennæ 7-segmented.
  a. Vertex of head without prominent bristles; antennal segments 3–5 about as wide as long; tube much shorter than head, relatively stout, three to five times as long as greatest width, with six long hairs at tip. **Urothrips** Bagnall.
  aa. Vertex of head with a pair of prominent, anteriorly-directed bristles; antennal segments 3–5 decidedly longer than wide; tube much longer than head, very slender, fully ten times as long as greatest width, with four long hairs at tip..... **Bradythrips** Hood and Williams.

II. Antennæ either 4- or 5-segmented.
  b. Antennæ 5-segmented.
    c. Vertex of head without prominent bristles; antennal segments 4 and 5 not closely united, 5 pedicellate; ninth abdominal segment less than twice as long as 8; tube with four long hairs at tip..... **Bebelothrips** Buffa.
    cc. Vertex of head with 4 to 6 prominent bristles; antennal segments 4 and 5 broadly joined; ninth abdominal segment at least twice as long as 8; tube with six long hairs at tip. **Stephanothrips** Trybom.
  bb. Antennæ 4-segmented; tube with four long hairs at tip. **Amphibolothrips** Buffa.

Genus **Urothrips** Bagnall.

1909. *Urothrips* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 126.
1911. *Urothrips* Bagnall, Ier Congr. Int. d'Ent., pp. 283–288.

Two species, both Ethiopian.

Key to Species.

a. Segment 7 of antennæ subequal in length to 6; tube about four-fifths the length of head. (German East Africa; Natal)..... **U. paradoxus** Bagnall.
aa. Segment 7 of antennæ nearly twice as long as 6; tube not more than two-thirds the length of head. (Natal)..... **U. bagnalli** Trybom.

Urothrips paradoxus Bagnall.

1909. *Urothrips paradoxus* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 127, Tab. III, Figs. 1–13.
1911. *Urothrips paradoxus* Bagnall, Ier Congr. Int. d'Ent., pp. 283–288.
1912. *Urothrips paradoxus* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 32.

Originally described from one male and one female taken in German East Africa, without data on habitat. Trybom had one female, taken under fallen leaves, Natal, January 31, 1905.

Urothrips bagnalli Trybom.

1912. *Urothrips bagnalli* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 33, Taf. 4, Figs. 33–44.

Known only from 4 ♂♂, 3 ♀♀, 1 prepupa, and 4 nymphs, taken under fallen leaves, Natal, January 31 and July 6, 1905.

Genus **Bradythrips** Hood and Williams.

1925. *Bradythrips* Hood and Williams, Psyche, Vol. XXXII, p. 68.

Only the following species is known. Neotropical.

Bradythrips hesperus Hood and Williams.
(Pl. II, Figs. 1 and 2).

1925. *Bradythrips hesperus* Hood and Williams, Psyche, Vol. XXXII, p. 68.

Female (apterous).—Length about 1.8 mm. Color straw yellow, with dorsum and front of head, pterothorax, and middle legs, brown; abdomen narrowly brown at sides of segments 2–9; hind legs with coxæ and middle of tibiæ brownish; tube dark brown at extreme tip; all tarsi with cup brown; antennæ nearly colorless, segment 7 often lightly grayish; subhypodermal pigmentation bright crimson-red, some in the darkened portion of head, none in prothorax, densest along sides of pterothorax, and continued into abdomen in two narrow streaks, one along either side of segments 1–8.

Head about 1.5 times as long as wide, broadest at about one-fourth from base, converging regularly to eyes and slightly toward base; occiput somewhat elevated; dorsal and lateral surfaces strongly roughened with tubercles which are largest on occiput, some of them bearing short, stout, dilated bristles; ventral surface smooth; vertex rounded in front of eyes, but scarcely overhanging insertion of antennæ, set with one pair of stout, pale brown bristles which are slightly expanded at tip and which arise from strong tubercles; postocular bristles wanting. Eyes minute, consisting of about three facets. Ocelli absent. Antennæ 1.2 times as long as head, seven-segmented (see Pl. II, Fig. 1, for form of segments); sense cones apparently absent.

Prothorax about one-half as long as head and (inclusive of coxæ) about twice as wide as median length of pronotum, surface without tubercles or sculpture of any kind and apparently lacking all bristles excepting a short, colorless pair, which are slightly dilated apically, at posterior angles. Pterothorax nearly twice as long and fully 1.5 times as wide as prothorax, trapezoidal, the sides widely diverging, its entire dorsal and lateral surfaces roughened with small tubercles interspersed with larger, spiniferous ones similar to those on head. Legs moderately stout; tarsi without claws.

Abdomen broadest at second segment and tapering evenly to base of tube; surface nearly smooth; each tergite with two transverse rows of short, dilated, colorless bristles; posterior angles of intermediate segments slightly produced and bearing a short, dilated bristle which is

parallel to the axis of the body; ninth abdominal segment about 2.8 times as long as eighth, surface nearly smooth. Tube about 1.6 times as long as head and about 1.6 times as long as ninth abdominal segment, slightly narrowed at middle and distinctly widened at apex, which is in width about one-twelfth the total length. Terminal hairs four in number, simple in structure, about 2.75 times as long as tube and half the total body length.

Measurements of holotype (♀): Length 1.81 mm.; head, length 0.201 mm.; greatest width 0.135 mm., width across eyes 0.108 mm.; eyes, length 0.027 mm.; prothorax, length 0.096 mm., width (inclusive of coxæ) 0.195 mm.; pterothorax, length 0.186 mm., greatest width 0.309 mm.; interval between fore coxæ 0.135 mm., middle coxæ 0.144 mm., hind coxæ 0.156 mm.; abdomen, greatest width 0.270 mm.; segment 8, length 0.072 mm.; segment 9, length 0.204 mm.; segment 10, length 0.330 mm., width at base 0.030 mm., at middle 0.019 mm., at apex 0.027 mm.; terminal hairs, length 0.912 mm.

Antennal segments:	1	2	3	4	5	6	7
Length (μ).....	21	33	40	36	34	33	45
Width (μ).....	27	30	22	21	21	18	16

Total length of antenna 0.242 mm.

Male (apterous).—Length about 1.3 mm. Almost identical with female in color and structure, though smaller. Tarsi unarmed.

Measurements of allotype (♂): Length 1.28 mm.; head, length 0.168 mm., greatest width 0.117 mm., width across eyes 0.087 mm.; prothorax, length 0.081 mm., width (inclusive of coxæ) 0.165 mm.; pterothorax, length 0.144 mm., greatest width 0.225 mm.; interval between fore coxæ 0.090 mm., middle coxæ 0.099 mm., hind coxæ 0.102 mm.; abdomen, greatest width 0.195 mm.; segment 8, length 0.060 mm.; segment 9, length 0.120 mm.; segment 10, length 0.237 mm., width at base 0.018 mm., at middle 0.014 mm., at apex 0.021 mm.; terminal hairs, length 0.720 mm.

Antennal segments:	1	2	3	4	5	6	7
Length (μ).....	21	30	37	30	30	30	48
Width (μ).....	25	27	21	21	21	16	13

Total length of antenna 0.226 mm.

Described from three females and two males, taken "at base of *Imperata* grass," Issoro, N. W. D., British Guiana, July 26 and August 3 and 6, 1916, C. B. Williams [Nos. 841, 847, and 848].

Genus **Bebelothrips** Buffa.

1909. *Bebelothrips* Buffa, Boll. Lab. Zool. R. Scuola Sup. Agr. Portici, Vol. III, p. 195.
1909. *Bebelothrips* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 136.

One species. Palæarctic.

Bebelothrips latus Buffa.

1909. *Bebelothrips latus* Buffa, Boll. Lab. Zool. R. Scuola Sup. Agr. Portici, Vol. III, p. 196, Figs. 2 D, 3.

Three females were known to Buffa, taken in January, 1909, Isola del Giglio, Italy.

Genus **Stephanothrips** Trybom.

1912. *Stephanothrips* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 42.

Two species. Ethiopian and Neotropical.

Key to Species.

a. Vertex with **two** pairs of strong, anteriorly-directed bristles; tube about 1.1 times as long as head and 1.3 times as long as ninth abdominal segment. (Natal).....**S. buffai** Trybom.

aa. Vertex with **three** pairs of strong, anteriorly-directed bristles; tube nearly 1.5 times as long as head and about 1.8 times as long as ninth abdominal segment. (St. Croix and Trinidad, West Indies).
S. occidentalis Hood and Williams.

Stephanothrips buffai Trybom.

1912. *Stephanothrips buffai* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 43, Taf. 5, Figs. 45–54.

Known from one male, one female, and one nymph taken under fallen leaves, Natal, January 31, 1905.

Stephanothrips occidentalis Hood and Williams.
(Pl. I; Pl. II, Figs. 3–5).

1925. *Stephanothrips occidentalis* Hood and Williams, Psyche, Vol. XXXII, p. 69.

Female (apterous).—Length about 1.4 mm. Color straw yellow with head, prothorax and fore femora, except apex, dark brown. Last two antennal segments dark brown, rest of antennæ light; fore tibiæ, mid and hind femora and tibiæ, darkened with brown at middle and along outer surface; tarsi with the usual darkened cup; lateral third or fourth of pterothorax and of abdominal segments 1–8, slightly darkened with brown, and with maroon-red subhypodermal pigmentation which continues in prothorax and head; median line of abdomen faintly indicated by a series of light grey blotches; ninth segment of abdomen narrowly darkened with brown along outer surface; tenth segment distinctly brightened with yellow, shading distally to dark brown at extreme apex.

Head about 1.13 times as long as wide, broadest at about one-fourth from base, converging regularly to eyes, and distinctly narrowed at base. Dorsal and lateral surfaces strongly roughened with tubercles which are largest and transversely elongated on occiput; ventral surface smooth; vertex broadly rounded and semi-circularly produced in front of eyes to overhang insertion of antennæ, and set along anterior margin with three pairs of blunt bristles which are slightly expanded at tip, the middle

pair about three-fifths as long as third antennal segment and curved inwards so that the tips almost meet, the two outer pairs shorter and straight, equal in length, the outer pair set close to, and at a lower level than, the other; each of these bristles arises from a strong tubercle; postocular bristles wanting. Eyes minute, consisting of about three facets. Ocelli absent. Antennæ almost as long as head, five-segmented, inserted below vertex; segment 1 subquadrangular, not visible in dorsal view; segment 2 broadly globose and pedicellate; segment 3 three times as long as wide, narrowly pedicellate at base, and slightly narrower at apex than at middle; segment 4 slightly longer than wide, broadest at middle subquadrangular, not pedicellate; segment 5 sharply conical, about twice as long as basal width. No sense cones present.

Prothorax about half as long as head and (inclusive of coxæ) two and one-half times as wide as long, with a broad, shallow depression on each side of the median line, in which are arranged irregular, subconcentric, dark, linear thickenings, interspersed with a few minute tubercles; a pair of short, stout, apically-expanded bristles arising from distinct tubercles, one at each hind angle of the prothorax; all other bristles wanting. Pterothorax about 1.45 times as long as prothorax, broadened posteriorly, greatest width about twice its length. Legs somewhat short and stout and roughened with minute tubercles; fore tarsus with a distinct, downwardly-curved claw on outer surface near apex; hind tarsus with a claw similar, but curved inwards; no claw apparent on mid-tarsus.

Abdomen broadest at second segment and tapering evenly to base of tube; surface nearly smooth; posterior angles of each segment slightly produced and bearing a short, dilated bristle which is parallel to the axis of the body; ninth abdominal segment about 2.6 times as long as eighth, width at apex 0.45 of greatest width, which is about one-fifth from base, surface with a few scattered, spine-bearing tubercles. Tube nearly 1.5 times as long as head and about 1.8 times as long as ninth abdominal segment, slightly narrowed at middle and distinctly widened at apex, which is in width about one-ninth of the total length. Terminal hairs six in number, simple in structure, and about 2.5 times as long as the tube, only slightly less than half the total body length.

Measurements of holotype: Length 1.44 mm.; head, length 0.177 mm., greatest width 0.156 mm., width across eyes 0.126 mm.; eyes, length 0.030 mm.; prothorax, length 0.090 mm., width inclusive of coxæ 0.225 mm.; pterothorax, length 0.129 mm., width 0.264 mm.; distance between fore coxæ, 0.126 mm., mid-coxæ 0.111 mm., hind coxæ 0.141 mm.; abdomen, greatest width 0.261 mm.; segment 8, length 0.057 mm.; segment 9, length 0.147 mm.; tube, length 0.261 mm., width at base 0.022 mm., at middle 0.019 mm., at apex 0.028 mm.; terminal hairs, length 0.660 mm.

Antennal segments:	1	2	3	4	5
Length (μ).....	24	30	81	21	30
Width (μ).....	22	30	27	18	13

Total length of antenna, 0.18 mm.

Described from three females taken by miscellaneous beating, St. Croix, Dutch (now American) West Indies, March 10, 1915, C. B. Williams [No. 554]; and from one female "swept under cacao," Verdant Vale, Trinidad, British West Indies, May, 1915, F. W. Urich [C. B. W. No. 722].

Type locality: St. Croix.

This species differs from *Stephanothrips buffai* Trybom, the only other species in the genus, described from Natal, in several particulars. The most important of these are the possession of six, instead of four, bristles on the vertex, and the relatively much longer ninth and tenth abdominal segments. Both of these characters are perhaps of sufficient importance to warrant the erection of a new genus; but at the same time it is believed that no useful purpose would be served by such a course, with our present fragmentary knowledge of this family.

Genus **Amphibolothrips** Buffa.

1909. *Amphibolothrips* Buffa, Boll. Lab. Zool. R. Scuola Sup. Agr. Portici, Vol. III, p. 193.
1909. *Amphibolothrips* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 136.

One species. Palæarctic.

Amphibolothrips grassii Buffa.

1909. *Amphibolothrips Grassii* Buffa, Boll. Lab. Zool. R. Scuola Sup. Agr. Portici, Vol. III, p. 194, Figs. 1 and 2, A, B, C.

Known from four females taken in December among dead leaves, Lake of Albano, Italy.

EXPLANATION OF PLATES.

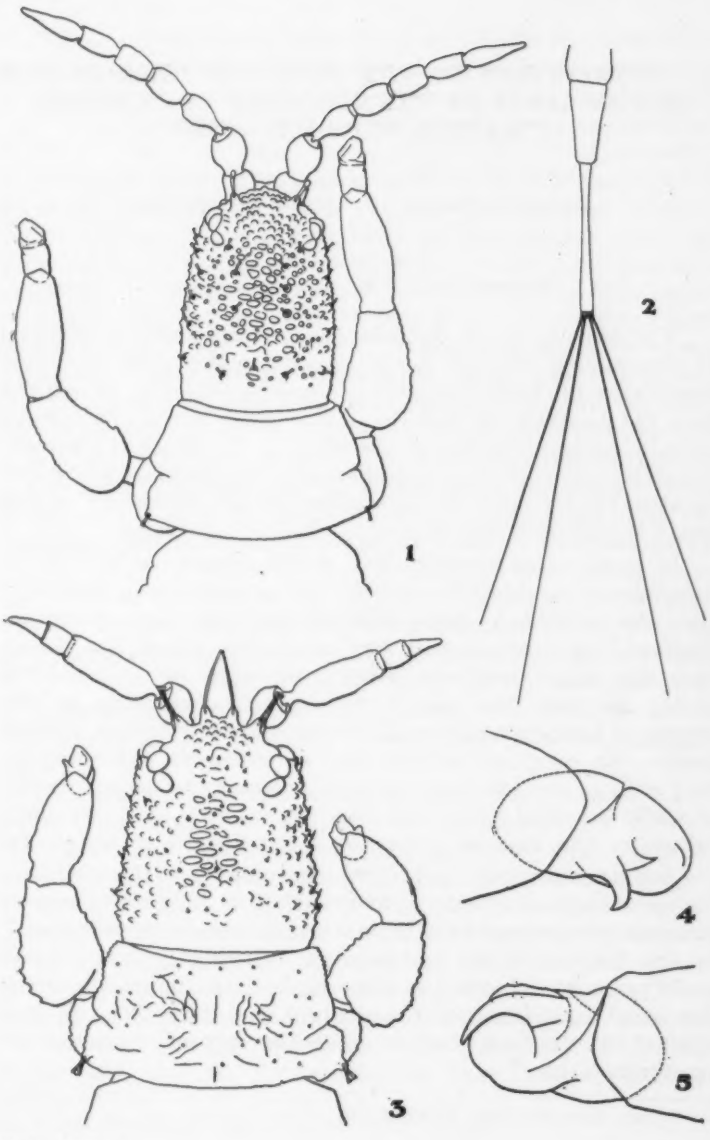
Plate I.

Stephanothrips occidentalis Hood and Williams, ♀, paratype.

Plate II.

(J. D. H. del., camera lucida).

Fig. 1. *Bradythrips hesperus* Hood and Williams. Head and prothorax, ♂, allotype. (Bristles on legs and antennæ omitted).
Fig. 2. *Bradythrips hesperus*. Tip of abdomen. ♀, paratype.
Fig. 3. *Stephanothrips occidentalis* Hood and Williams. Head and prothorax, ♀, holotype. (Bristles on legs and antennæ omitted).
Fig. 4. *Stephanothrips occidentalis*. Right fore tarsus, ♀, paratype.
Fig. 5. *Stephanothrips occidentalis*. Left hind tarsus, ♀, paratype.



Hood and Williams.

A CONTRIBUTION TO THE STUDY OF HIBERNATION IN THE LARVA OF THE EUROPEAN CORN BORER (PYRAUSTA NUBILALIS HUBN.)

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and
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The importance of variations of environmental conditions in determining changes in the seasonal history and economic importance of dangerous insects is now so generally recognized that the program of study of major pests practically always includes an investigation of the effect of the principal meteorological factors, with the object of establishing definite correlations between variations in the destructiveness or life history of the insect studied and fluctuations in climatic conditions.

In many cases investigations of this type have brought to light facts of considerable interest. It seems probable, however, that the problem is more difficult than has been supposed. Shelford,* in a recent and very suggestive paper, has shown that the simple methods hitherto in vogue are of doubtful utility and that the laws of development arrived at by the system of temperature summation are valid only within narrow limits. So complex, indeed, and so extensive, according to this author, are the investigations necessary to secure results of really practical value that they can rarely if ever be undertaken by the average group of entomological investigators.

Among the many factors which complicate the problem, Professor Shelford mentions particularly "the difference between different generations of the same species in respect to responses." In the Codling Moth, for example, "there may be as much as 20 per-cent difference in the length of the pupal life under the same conditions of temperature and humidity, as calculated or observed, due to preceding rainfall, variation of temperature, etc."

* Journ. Econ. Ent., Vol. 19, No. 2, 1926.

There are, however, many cases, as yet, for the most part, imperfectly studied, in which the variation in the velocity of development from generation to generation is much greater and much more difficult to explain than in those cited by Shelford. Such are the insects which present at recurring intervals in their phylogenetic history the phenomena of arrested development which are usually classified roughly under the head of "hibernation" or "aestivation" but are more correctly designated by the term "diapause," proposed originally by Wheeler in connection with certain embryological phenomena and extended by Henneguy to cover resting stages at any period of the life history. It has been shown by recent experiments that insects which have passed into a diapause can be exposed for long periods of time to conditions inducing rapid transformation with normal individuals without any appreciable effect in so far as the velocity of development is concerned. The most general treatment of the matter seems to be that due to E. Roubaud, who published in 1922,* an extremely interesting paper giving the results of his investigation of the resting condition in the Muscoid diptera, among which he observed a number of cases of suspended development having apparently no relation to fluctuations in surrounding temperatures. More recently, an analogous condition, which K. W. Babcock has discussed from several standpoints in a series of excellent papers, has been found to occur in the life history of the European Corn Borer (*Pyrausta nubilalis Hubn.*)

In certain areas, both in Europe and in America, the European Corn Borer has usually two generations per annum. The larvæ of the first generation, issuing from eggs deposited in early spring, pupate during late July and August, emerging as adults in about two weeks. But the larvæ of the second generation, after reaching a condition of apparently complete development in the fifth stage toward the latter part of September, pass into a lethargic condition from which they do not emerge until the following spring. In other regions, however, the larvæ of the first generation, which reach the fifth stage rather late, instead of transforming, pass into the dormant

* Bull. Biologique France Belgique, T. LVI, Fasc. 4.

condition like those of the autumn brood in the second-generation areas. It was at first thought that the condition of hibernation was directly determined by the prevailing meteorological conditions, but on investigation this hypothesis proved to be unfounded. It was found impossible to apply to the hibernating larvæ the results obtained from the study of the individuals of the summer generation. The experiments carried on by Mr. Babcock, as he has shown in his paper on the dormant period of *P. nubilalis*, demonstrated clearly that the diapause of the overwintering larvæ of this insect is something quite different from the lethargy induced by mere low temperature, and that the dormant individuals cannot be reactivated except in small members with a high rate of mortality by exposure to high temperatures, though every effort was made to reproduce as exactly as possible the conditions prevailing during the developmental period of the summer brood.

The exact nature of diapauses, considered from the physiological standpoint, is as yet little understood. The only really comprehensive hypothesis that has been proposed is that of E. Roubaud. This author, whose opinion is based upon a number of ingenious experiments and arguments believes that the cessation of development is due to an autointoxication of the organism, whose excretory system is unable to keep pace with the accumulation of waste material which occurs in periods of rapid development, especially after several generations of uninterrupted multiplication. The period of repose at low temperatures, which according to Roubaud can be replaced in the case of certain Muscids by a number of different physiological stimuli, is considered by him to be a time of physiological purification, during which the excess of excretory material is little by little eliminated.

Among the observations mentioned by Roubaud in support of his hypotheses those connected with the histology of the excretory system in the hibernating species occupy an important place. He claims that there are well-marked differences between the hibernating and reactivated larvæ. At the beginning of hibernation the cells of the adipose tissue and the Malpighian tubes are filled with urate granules; in larvæ which have resumed activity these granules have disappeared, while the cells of the excretory organs have the appearance of elements exhausted by a prolonged period of intense activity.

The study of these results led us to hope that by examination of the excretory system of the larvæ of the corn borer it might be possible to identify the various phases in the development of the hibernating larvæ. We therefore made a series of careful dissections of overwintering specimens from all the most important regions in Europe, both during the period of hibernation and after emergence therefrom. In a considerable number of larvæ the Malphighian tubes were found to be irregularly swollen, the cells being filled with granular material. This was at first thought to be excretory in origin, but the application of the usual tests for uric acid gave negative results and on more careful examination it was found that the granules present were in reality parasitic protozoa which were subsequently determined by Dr. White of the Bureau of Entomology as Sporozoa of the Nosema group. So far as could be determined, there is apparently no relation between the presence of these organisms, which, in parentheses, seem to have little if any importance as pathogenic agents, and the phenomena of hibernation.

No other clear-cut differences were observed between the excretory organs of the hibernating and active larvæ of *P. nubilalis*. However, during a further series of dissections, undertaken chiefly in connection with the biology of the parasites of the borer, it was observed that as the spring advanced certain very definite changes occurred in the rudiments of the reproductive organs. These changes take place in the organs of both sexes. In the female larvæ they are difficult to follow accurately because of the minuteness of the ovarian rudiments in the caterpillars, but in the male larvæ they can be very easily studied. It was therefore decided to undertake a series of observations on the development of the genital organs in the male caterpillars, with the results described in this paper, which is offered not as a complete treatment of the problem of hibernation but simply as the outline of a method by which it can be attacked.

The rudiments of the male reproductive organs of *Pyrausta nubilalis* consist in the hibernating larva of a pair of small kidney-shaped bodies measuring approximately 0.75 mm. in length by 0.45 mm. in width, situated on the dorsal wall of the body cavity, ventrad of the heart, in the 8th body segment.

They are more or less firmly attached to the dorsal bands of adipose tissue and are held in place by the tracheal branches from the 8th segment. In each gonad can be distinguished 4 piriform compartments each of which opens at the smaller end, situated toward the mid-dorsal line, into a common duct, the vas deferens which is a long slender tube running posteriorly from the gonad along a line close to the middle of the dorsum until it reaches the 12th segment, where it bends abruptly downwards, passing under the tracheal trunk and terminating in a button-like prominence on the floor of the 12th segment. Between these button-like terminations of the vasa deferentia, on the floor of the segment, is found a spherical sack with a short, wide, tubular mouth attached to the ventral body wall. This sack, which is divided vertically into two equal compartments, apparently does not open to the exterior in the larval stage.

It is interesting to note that in 1762, in his celebrated treatise on the anatomy of *Cossus ligniperda*, the French entomologist Lyonnet gave a very accurate description of the larval gonads. He was not quite clear as to their exact significance, but strongly suspected that they were the rudiments of reproductive organs.

The histological structure of the gonad varies according to the age of the larva. In each of the four compartments is a large number of testicular ampullæ or spermatocysts of which several types can be distinguished in the prepupal larva. The youngest and smallest of the ampullæ usually lie along the wall of the distal extremity of the organ while the older, containing spermatozoa in various stages of formation, lie toward the small or proximal extremity. When the testicle is torn open in a drop of saline the ampullæ rush out and float freely in the liquid as independent and unattached bodies, varying in form from globular to elongate cylindrical according to the state of development. All of the cells in an ampulla appear to be in practically the same stage. The "zones of development" distinguished by the cytologists in the testicular tubes are thus represented in the gonad of the Lepidopterous larva by a series of ampullæ of different ages between which, however, no well-defined boundaries exist.

The youngest ampullæ form the germinative zone in which the primordial germ cells or spermatogonia multiply by division,

but conserve their primitive dimensions. The next group constitutes the zone of growth in which the spermatogonia of the last generation increase in size and divide to produce the spermatocytes of the first order. The last two groups correspond respectively to the zone of division and reduction, in which are produced the spermatids, and the zone of transformation of the spermatids into the spermatozoa.

The resumption of activity by the hibernating larvæ is characterized by the swelling of the reproductive rudiments. As the organs enlarge, becoming in the process more rounded in outline, the distance between them diminishes and eventually they fuse together on their inner edges, assuming a spherical form. This latter condition is generally found in the prepupal larvæ, though development is sometimes retarded in certain individuals.

As the age of the larva can be estimated from the conditions of the gonads, it is important to be able to recognize the various phases of this development, We have therefore defined four stages in the growth of the organs and have classified the larvæ dissected into this arrangement. As the development of the testicles is gradual and continuous, the definitions given are necessarily somewhat indefinite. It is believed, however, that they will permit a classification of larvæ sufficiently accurate for the study of the life history of the corn borer.

In phase 1 the average testicle measures about 0.75 mm. in length by 0.45 mm. in width. It is reniform, with rather depressed and acute edges; the four compartments are distinctly visible; the organ in this stage is pearly white in color.

In phase 2 the average measurements are 1.0 mm. in length by 0.5 mm. in width; the form is about as in the first phase but is more rounded, the edges being much less acute; the four compartments are very distinctly outlined, being more clearly defined than in the preceding stage.

In phase 3 the average dimensions are 1.25 mm. in length by 0.5 mm. to 0.6 mm. in width. The gonad is now more oblong in outline and is greatly swollen; the edges are now rounded, the compartments still visible but indistinct.

In phase 4 the reproductive rudiment measures 1.75 by 2.0 mm.; the two testicles are now grown together and form an almost spherical mass, slightly flattened in the dorso-ventral direction. The general consistency is less solid than in the

preceding stages, the walls being thinner and less resistant; the color is usually yellowish.

After a considerable number of gonads had been obtained and classified on the basis of their external morphology, they were sectioned for a cytological examination. Material for this work was obtained from various areas in France, including the one-generation districts of Lille, Paris, Angers in the north, the two-generation district of Hyeres in the southeast, and the transitional district around Auch in the southwest.

Fig. 1. Reproductive system of male larva of *Pyrausta nubilalis* Hubn. showing the testicle and duct of one side and the unpaired pouch in segment XII.
Fig. 2. Reproductive organs of male larva of *Pyrausta nubilalis* Hubn. Phase I.
Figs. 3–5. Reproductive organs of male larva of *Pyrausta nubilalis* Hubn. Phases II, III and IV.

The cytological condition of the phase 1 gonads was very uniform. The ampullæ contained only spermatogonia and spermatocytes of the first order. As the cells in the proximal region of the compartments are considerably longer than in the distal region, an increase in size has evidently taken place, but the only division figures observed were among the smaller cells. In this stage therefore there are represented in the

testicle the germinative zone and the zone of growth excluding, however, the phase of division between the spermatocytes of the first and those of the second order.

The condition found in the phase 2 gonads was somewhat more variable than in the preceding phase, as the morphological characters utilized for its identification are necessarily rather ill-defined.

Generally speaking, this stage is characterized by an increase in size of the spermatocytes and by the appearance of division figures. We have made no attempt to decide whether the divisions observed are those giving rise to the spermatocytes of the second order or the maturation divisions. In any event, the appearance of the mitotic figures, which are very apparent and usually appear simultaneously in all the cells of a given ampulla, seems to be a definite indication that the larva has emerged from hibernation.

The phase 3 gonads are also variable but characterized for the most part by the appearance of spermatocytes containing spermatozoa in process of development, but still not perfectly formed, mixed with ampullæ still containing spermatocytes, many in various stages of division.

In the fourth phase the gonads contain little else but elongate spermatocytes filled with spermatozoa of which many are completly formed, though a few ampullæ in earlier stages are present here and there.

The result of dissections made to determine the main facts in regard to the development of the male reproductive organs are summarized in the following table, the most important data of which are represented graphically in charts I to VI. The proportions of the various stages present in each lot of larvæ have been calculated as percentages. As the number of larvæ dissected was in all cases inferior to 100, this procedure is of course open to serious objection as there is in fact no proof that the proportions of individuals in the various phases would have been the same in the remainder of the 100 larvæ required for the calculation of a true percentage. However, although the probable error in each individual case is very great, the general trend of the developmental processes as represented in both the charts and the tables is for the most part essentially the same, so that the data are probably sufficient to give a rough idea of the progress of events. In order to

simplify the charts and tables, we have lumped the larvæ in phases 3 and 4 under one heading.

In spite of the fragmentary character of the data available, it is evident that the study of the reproductive organs affords an easy method of ascertaining with a fair degree of accuracy the stage of development of larvæ which it is quite impossible to classify by means of external characters.

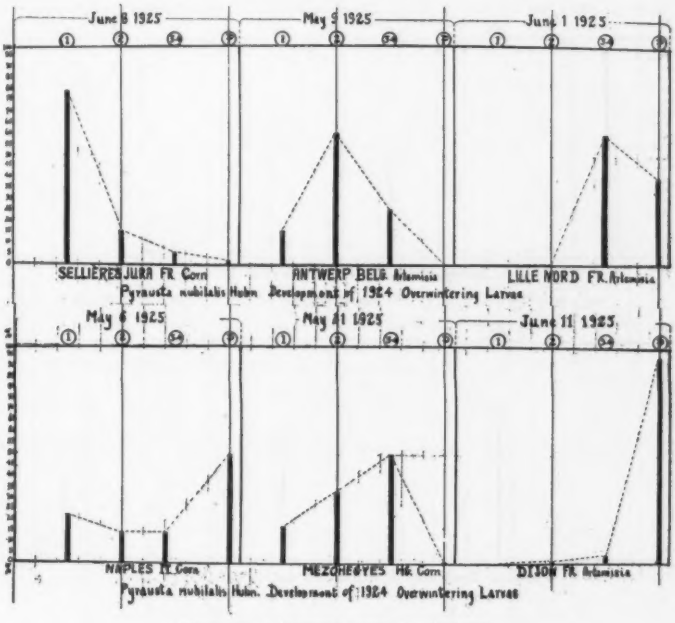
TABLE I.

Locality	Type	Generation	Date	No. of larvæ examined	Phase 1.	Phase 2.	Phases 3 and 4	Pupæ
					%	%	%	%
Antwerp, Belgium	1-G	Winter	May 9, 1925	20	14.9	59.70	24.97	0.43
Lille, France.....	1-G	"	June 1, "	3	.....	.....	60.0	40.0
Dijon, France.....	1-G	"	June 11, "	19	0.0	0.52	4.47	95.0
Sellieres, France..	1-G	"	May 8-9, "	20	79.0	14.9	4.8	1.2
Mezohegyes, Hungary.....	1-G	"	May 21, "	18	16.6	33.3	50.0	0.0
Auch, France.....	Transitional	"	May 9, "	24	95.9	4.1	0.0	0.0
" "	"	"	May 29, "	20	50.0	35.0	15.0	0.0
" "	"	"	June 9, "	14	6.9	41.5	48.5	3.0
Valence, France...	"	Summer	Sept.2-3 "	45	91.8	2.2	0.0	6.0
Bergamo, Italy....	2-G	Winter	May 9, "	14	50.0	50.0	0.0	0.0
" "	2-G	"	May 14, "	58	8.5	18.6	70.7	2.2
" "	2-G	"	June 13, "	26	0.0	5.0	38.5	56.4
Naples, "	2-G	"	May 6, "	7	22.0	14.0	14.0	50.0
Hyeres, France....	2-G	"	May 9, "	22	44.4	40.2	13.3	2.0
" "	2-G	"	May 30, "	19	4.0	20.3	57.0	18.5
" "	2-G	Summer	June 30, "	5	40.0	60.0	0.0	0.0
" "	2-G	"	July 3, "	5	60.0	40.0	0.0	0.0
" "	2-G	"	July 7, "	19	5.25	5.25	89.5	0.0

By suitable dissections we can thus detect a difference between the populations of various areas even before the time of pupation. A comparsion between the results obtained by the examination of the overwintering larvæ from Mezöhegyes, Hungary, on May 21, with those secured by a study of larvæ from Auch, France, and Gergamo, Italy, on May 9, is very suggestive in this connection.

Again, the examination of the gonads constitutes an easy and practical method of determining the approximate moment of emergence from hibernation and the progress of this process in any given area. It is probable that when the larvæ have

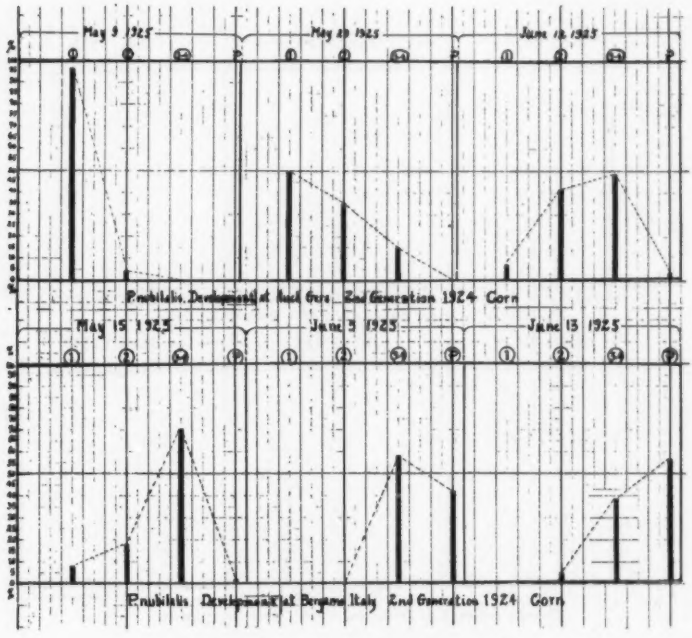
emerged from hibernation their development is governed by the laws which normally prevail and can be expressed in terms of equations representing a few main factors such as temperatures and humidity. It is true that the actual moment of emergence from hibernation cannot be determined, but it is probable that when larvæ with reproductive organs in phase 2 begin to appear the majority of individuals have passed into



CHARTS I (above) AND II (below)

a condition of physiological activity. It should thus be possible, by combining the method here described with suitable experiment, to predict the moment of the height of emergence from hibernation and to determine the laws of development from the time of emergence until the issuance of the adult insects. This would give us a sufficient grasp of the problem of the development of the overwintering larvæ for most practical needs.

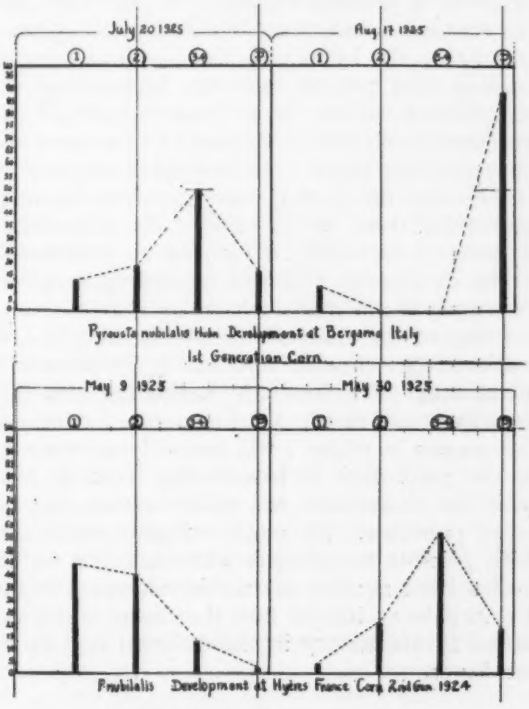
There are also indications that the study of the development of the larval gonads may throw some light on the problem of the causes of the hibernating condition. For example, some dissections of summer generation material made at Hyeres in 1925 show that in certain stage IV larvæ the gonads are already in phase 2 and that in the stage V individuals


May 9 1925
May 29 1925
June 18 1925
Probable Development of 2nd Gen. 2nd Generation 1924 Corn
May 15 1925
June 5 1925
June 15 1925
Probable Development at Bergamo Italy 2nd Generation 1924 Corn

CHARTS III (above) AND IV (below)

they develop very rapidly. On the other hand, in stage V larvæ examined even late in the summer, in a pure one-generation area, the gonads are all in the first stage. We may thus conclude that the inhibition of development affecting the imaginal organs is determined by factors operating at a fairly early stage in the larval life and is to a great extent if not completely independent of conditions prevailing in the height of the summer months, an idea already expressed by Mr. K. W. Babcock on the basis of his experimental studies. It is also

interesting to note that the larval organs continue to develop in the individuals predestined to hibernate until the point when they are completley formed; that the arrest of development affects only the imaginal rudiments, and that the histolysis of the larval organs begins only after the histoblasts have


July 20 1925
Aug 17 1925
Pyrausta nubilalis Hbn. Development at Bergamo Italy
1st Generation Corn
May 9 1925
May 30 1925
Nubilalis Development at Hyères France Corn 2nd Gen 1924

CHARTS V (above) AND VI (below)

resumed activity. These facts would seem to indicate that the degeneration of the larval tissues preparatory to metamorphosis is in some way dependent upon the development of the imaginal tissues.

At all events, the difference in the rapidity of development of the gonads in the larvæ of the hibernating and non-hibernating types makes it possible by dissections to define fairly accurately the character of the larval population in transitional

areas. For example, the dissection of 67 larvæ collected at Bergamo, Italy, in 1925, at a time when 17 per cent of the population had pupated, showed 11 in phase 1, 15 in phase 2, and 41 in phase 3. Now as the tables and charts indicate, by the time 17 per cent of the individuals have pupated practically no larvæ in phase 1 remain in a pure two- generation area. The continued occurrence of larvæ in this phase seemed explicable only on the hypothesis that a certain proportion of the population had passed into the hibernating condition. Collections made a month or so later supported this view. A lot of specimens collected on August 13-17 showed 89 percent pupæ and 11 per cent larvæ. Twenty six larvæ were dissected and in all of these the gonads were found to be in phase 1. On the date mentioned 79 per cent of the individuals in the field had emerged as adults, a fact which indicates that on this date the development of the summer generation in this region was nearly complete.

A good idea of the character of the larval population in a transitional area can thus be obtained by making a series of dissections of stage V individuals, neglecting preferably such specimens as have just moulted. The percentage of individuals having the gonads in phase 1 will probably approximate fairly closely to the percentage of hibernating larvæ in the region, especially if the dissections are made during the height of the period of pupation. By means of appropriate dissections it should be possible to evaluate with sufficient accuracy the character of a large number of transitional areas from year to year and thus gain an insight into the causes which determine the variations in life history in the different regions inhabited by the corn borer.

NOTES ON THE LIFE HISTORY, DISTRIBUTION AND ECOLOGY OF DIOTREPHA MIRABILIS OSTEN SACKEN.

J. Speed Rogers,
University of Florida.

Diotrepha mirabilis, new species and new genus, was described by Osten Sacken in 1878.* At the time the description was written he had no specimens before him, but based his account on his notes and memory of two specimens: one, designated as the type, taken by himself in Georgia in 1858; the other taken in Texas by a Mr. Boll. These two specimens constitute the only published records of *Diotrepha mirabilis* from the continent of North America, although Osten Sacken mentioned a third specimen, from Cuba, that he had seen in Loew's collection, as being probably the same species, and Williston† records the species from St. Vincent, where the collector, Mr. H. H. Smith, made the notes: "Abundant in forest glen 1000 ft.; near a stream; Sept. Alights on the lower sides of leaves."

During the past several years I have had the opportunity to observe, collect, and rear this cranefly in several localities within the United States. On June 14, 1921, while collecting with Dr. C. P. Alexander, in Jefferson County, Indiana, we took some six specimens while sweeping the vegetation along a small, shady, marshy, spring rill that ran through a beech woods. In June of the following year, several more adults were taken from the same situation and some larvæ and pupæ, of what proved to be this species, were discovered in a wet, rotten, sweet gum log that lay at the margin of the rill.

In Florida, *Diotrepha mirabilis* has been taken in four widely separated localities in the northwestern and central parts of the state. Washington County, a single teneral specimen from a "bay-head" (a swamp of mixed broad-leaved

* Osten Sacken, C. R., Catalogue of the Diptera of North America, Second Edition. Smithsonian Misc. Col. 270; Washington, 1878.

† Williston, S. W., On the Diptera of St. Vincent (West Indies); Trans. Ent. Soc. London for 1896, Part III.

trees), June 18: Liberty County, a specimen from the shaded bottom of a beech-savarn-magnolia ravine of the Apalachicola River, and abundant and emerging in numbers in a creek-bottom gum swamp, July 26 and 27; Alachua County, from a black gum swamp and from two separate marshy, shaded, brook ravines, March, April, May, June and August; Marion County, from a low hammock along a creek bottom, April 4.

Intensive collecting in other localities in Florida and in Georgia, North Carolina, and Tennessee have, so far, failed to discover this fly.

The existence of the imago is brief, even for a cranefly. Out of more than a hundred that have been reared, none have lived for more than 48 hours and this in cages where other craneflies, (*Epiphragma solatrix*, *Dicranomyia rara*, *Atarba picticornis*, *Teucholabis complexa*), emerging from the same rotted wood were active and vigorous from four to six days. When copulation takes place soon after emerging, the duration of adult life is even more brief. In only two cases out of more than twenty did either member of a pair live more than eighteen hours after copulation was completed. Both of these were females. Collection in the field, on the only occasion when adults were taken in numbers, consisted of a large percentage of teneral individuals and most of the others appeared to be but recently hardened.

The adult appears to be closely restricted by atmospheric moisture. In all situations in which adults have been found deep shade and saturated earth combine to make the surrounding air very moist. In a narrow, shaded brook ravine on the University of Florida Campus, careful collecting has been done at frequent intervals. All the flies taken have been from about or beneath dense fern clumps that grow from saturated soil along the bottom of the ravine. In this narrow zone adults have been taken for a considerable distance along the ravine, but none have ever been found outside of this tenfoot wide, wet strip, although the rotten wood from which scores of empty pupa skins project lies near the outer margin of the wet area.

In the fall, winter and spring of 1923–1924, Dr. Frank A. E. Thone, then Professor of Botany at the University, ran a series of atmometers along a cross section of the ravine. This line included the area from which *Diotrepha mirabilis*

had and has been taken, and the drier slopes to either side. The atmometer readings showed marked and persistent evaporation differences between the narrow, moist bottom of the ravine and the slopes to either side and although the evaporation rate increased farther up the slopes and on the level ground at the top of the ravine, the most marked increase was that from the ravine bottom to the lower slopes. Apparently this region of marked evaporation increase coincides with the limits of the fly's habitat.

Nearly all of the flies that have been observed in the field have been at rest, clinging to the under side of leaves and fronds. When disturbed, they fly upward until they come into contact with another surface. Should the fly chance to touch the upper surface of a leaf, while in flight, it alights and at once walks over the edge to come to rest suspended from the lower surface. After some preliminary bobbing, hold is maintained with meso-and metathoracic legs, the body hanging well away from the leaf and parallel to it and the prothoracic legs projecting downward and forward, beyond the body.

In flight the fly resembles a bit of thistledown drifting in the air. Although the small wings move rapidly and give good progress, the long trailing legs and body make any breeze cause considerable leeway. For this reason the precise spot on which the flying insect will come to rest, seems partly a matter of chance.

On several occasions I have observed a small Asilid capture individuals that were in flight.

Strong light is avoided. Full sunlight falling upon or reflected upon a resting fly will cause it to move, but the light of ordinary north shade is not avoided. At night females will come to a lighted sheet, even for a distance of a hundred yards.

I have never observed *Diotrepha mirabilis* to feed, but one individual was observed with the mouthparts applied to a drop of water on the underside of a leaf. The mouth parts were in contact with the drop of water for nearly a minute and then the fly resumed the usual resting position, lowering the body well away from the leaf and the drop of water.

A pair in copulation were observed in a gum swamp in July. The female clung to the underside of a small leaf, at a height of about six feet. She was hanging by the two anterior

pairs of legs, while the metathoracic pair hung limply down. The male hung head down with no other support than the clasp of his genitalia. In cages in the laboratory, the flies copulate freely and the whole process can be followed with considerable detail. When a male and a female are put into the same cage, both rest quietly from the top or sides of the cage with only occasional changes of position, until such movement results in the two flies coming in contact. Even the slightest touch of any part of the bodies or their appendages serves to arouse the male to immediate activity. He flutters about until he is again in contact with the female and as rapidly as possible takes a position in which his body is dorsad to hers, that is, parallel to hers, but farther out from the support. his legs straddling her body to obtain a foothold on the same support to which she clings. At the same time the basistyles of the male are spread open into a shallow V and the dististyles are opened to their widest extent so that they project directly caudad and are parallel. The whole structure forms a pair of widely opened forceps. The long slender abdomen of the male bends into the shape of a shallow fish hook, the genitalia at the apex, so that although his thorax is dorsad to the thorax of the female, the middle of his abdomen passes ventrad to the female's abdomen and the distal third of his abdomen curves sharply dorsad again to bring the opened forceps towards the female's abdomen from beneath. The forceps are moved about vigorously, feeling for the female's abdomen. The slightest touch on the inside of the forceps causes them to snap shut, the basistyles folding together and each dististyle snapping against its basistyle like a knife blade into the handle. Frequently the forceps shut upon the female's or his own legs but in such a case the forceps are quickly opened again and the feelng about is resumed. Once the forceps close about the female's abdomen, usually in the region of the fifth to seventh somite, the hold is retained, although loosened enough to allow the encircling ring of basistyles and distisyles to be quickly slid caudad along her abdomen to the base of the ovipositor. Here the flexed dististyles meet or overlap at the base of her ninth abdominal tergite, and their position is retained while basistyles are still pulled caudad, with considerable stretching, around the tips of the sternal valves of the ovipositor. In executing this movement the abdomen of the male is sharply bended and his feet are

moved backward to carry his body farther back. As the basal angle of the forceps slips over the sternal valves of the ovipositor, the dististyles are strongly flexed and the genital chamber of the male is drawn over the sternal valves as a scabbard might be thrust over a sword. In some cases this part of the process causes some difficulty and considerable effort is made before the sternal valves slip properly into place. Apparently, coincident with the enveloping of the sternal valves, the penis is inserted but the whole movement is rapid and observation is difficult because slight movements on the part of both flies makes it impossible to maintain a sharp focus with a binocular, or even a hand lens. Once the sternal valves of the ovipositor are properly fitted into his genital chamber, the male lets go his foothold and slowly bends downward, at the same time rotating the anterior end of his body, to hang head down, supported only by the hold of his genitalia. Should his feet chance to come into contact with some support he may take hold, but frequently does not.

The obtaining of the copulatory hold takes from one to three minutes and is marked by considerable exertion and activity. Once the male has turned about to hang head down, or to face in the opposite direction, both flies rest quietly for thirty to forty minutes. At the end of this time both become restless and begin to move about. The male may turn back toward an upright position, using the female's body as a foothold to scramble back to the overhead support. Often, however the movements of the female bring the male's sprawling feet into contact with some supporting surface before or while he attempts to reach the overhead support. Once the male has his feet in contact with a solid support the flies quickly separate with little effort. Once separated both flies rest quietly for some minutes, after which the male begins to occasionally walk or fly about, ready to repeat the process with another, or the same, female at the slightest contact. In, at least, one case the second female laid fertile eggs and had not paired with another male.

The female usually waits until dusk or night to begin ovipositing. A fertilized female that seems sluggish in the afternoon will often be found actively at work, laying eggs when a flashlight is turned on her cage at night. Some females, however, begin ovipositing in the daytime. In

ovipositing. the female climbs slowly and awkwardly over the pieces of rotten wood in her cage, touching her ovipositor to the surface of the wood from time to time. After touching some spots, the tips of the ovipositor are pressed more firmly against the wood and a slow, rythmic movement of the legs and abdomen begins, that forces the tips of the ovipositor beneath the surface of the wood. There is then a pause, the valves of the ovipositor open slightly, another pause, and the ovipositor is withdrawn without appreciable effort. In some instances the chosen spot is abandoned after an effort to force the ovipositor into the wood. In nearly all cases the chosen spot is on a vertical or nearly vertical surface of the wood. The egg is placed at a depth of about a millimeter and usually lies at the juncture of the most rotten and more sound wood.

All of the wood from which larvæ or pupæ have been taken, or from which adults have been reared, has been in a similar stage of decay. It is saturated or almost so, the bark gone, and with a thin black surface layer of moist, rotten, wood-dust. Beneath this thin sludge the wood still shows the annual rings, but these readily separate into flaky pieces with the pressure of a finger nail. Deeper, the wood may be much more firm. Magnolia, black gum, bay, sweet gum, and red maple in this stage of decay have been found containing the larvæ or pupæ of *Diotrepha mirabilis*. The broken ends of the logs and large branches frequently show areas of wet spongy decay, that are green with thin patches of algæ and these areas are also occupied by the immature stages. Wood in the proper stage of decay, whether large trunks, or twigs the diameter of a lead pencil, may be inhabited. In the larger logs, frequently only a narrow zone, next to the wet soil, is inhabited, the upper parts of the circumference still too sound to be available. In a magnolia log that was observed in 1923, 1924 and 1925 the inhabited zone has crept upward with the progress of decay from the bottom third of the circumference in 1923 to the top area in 1925, the bottom, by that time, too rotten for occupancy. The inhabited wood often shows signs of former use by *Passalus cornutus* and other wood boring beetles, but these have disappeared or are far deeper within the wood, by the time *Diotrepha mirabilis* appears. Contemporary inhabitants with *Diotrepha mirabilis* are the craneflies: *Epiphragma fascipennis* (Indiana); *Epiphragma solatrix*; *Elephantomyia westwoodi*; *Dicra-*

nomyia rara; *Atarba picticornis*; and *Teucholabis complexa*, although several of these are found in wood in other stages of decay as well.

The larvæ and pupæ are found close to the surface of the wood, either the circumference, ends, or in crevices. They have indefinite, short burrows, usually between two of the rotted annual rings, but sometimes through the frass of an old Passalus cornutus burrow. Nearly always the burrows and the larvæ and pupæ are parallel to the nearest surface of the wood. Often the burrows have openings to the surface at one end but the surface is so spongy and soft that it is impossible to be sure whether openings are always present or not. These burrows are not over three or four times the length of the full grown larva and are lined with a thin, opaque, delicate sheath. In the burrows of the young larvæ this sheath is scarcely evident but in the case of older larvæ it forms a complete lining of the occupied part of the burrow, and pupation takes place within this sheath.

The immature stages are apt to be very numerous in wood in which they occur at all. Thirty larvæ and pupæ have been taken from an area three inches by one half inch, all within two millimeters of the surface. The larvæ are very sluggish but move when uncovered or touched, forward or backward in the burrow. Movement is accomplished mainly by dilating the terminal segements of one end and then lengthening the rest of the body; the terminal segments of the other end are then dilated and the rest of the body shortens, a series of alternating pushes and pulls. Creeping welts are present and are probably used, but the greater part of locomotion is due to the process described above.

Both the larvæ and pupæ are exceedingly delicate and with the best of care at least half of those found are injured in removing them from the wood.

The food of the larvæ, as indicated by smears from the digestive tract, consists of the soft rotted wood and the microscopic lower plant life that grows in or from it. Among these lower plants are desmids, diatoms, and the filamentous algæ Gleothecia, Nostoc, and Rivularia.* Some larvæ have been reared from egg to maturity in wood which showed very little

* Identifications made by Prof. M. D. Cody, University of Florida.

microscopic plant life, but these larvæ were paler in coloration and smaller at pupation than larvæ taken full grown from rotten wood in the field.

In Florida there are two generations a year and, although the seasons are not clear cut, the adults are most numerous in March and April and in July and August. In the breeding cage, eggs laid by adults that emerged in August were minute larvæ in September, were full grown larva in late February, and emerged as adults from March 20 to 30. Larvæ of about the same size as the September larvæ, above, were taken from a rotten log in late April, 1926 and adults appeared in July and August. Because of their delicate structure and wood-burrowing habit, it is difficult to follow the development of the larvæ. Shortly after hatching, the larvæ have a length of from 3 to 4 mm.; in two months the length is from 8 to 9 mm.; when full grown from 10 to 13 mm. The younger larvæ are almost transparent and very slender, but the markings and shape of the spiracular disk, to be described below, are characteristic, although the coloring is faint.

Several full grown larvæ, placed with wood pulp between glass slides that were separated by little more than the diameter of the larvæ, were observed to pupate. The larvæ become quiet and the color fades to a dirty yellowish white. About two days after the larvæ become quiet, the faint outlines of the pupæ become visible, and at about this time the larval skin splits in the thoracic region with the emtpy head capsule still enclosed in the first thoracic segment. Slight movements of the pupa serve either to withdraw the pupa farther from the larval skin or else to force the skin caudally from the thoracic region. Probably both forward movements of the pupa and wriggling, that forces the larval skin backward, serve to free the pupa from the larval skin, although after four or five days in the pupa stage only the head, thorax and first few abdominal segments are free from the larval skin, the empty end of which doubles back over that part of the abdomen still encased, like the fingers of a glove that are turned wrong-side-out as they are pulled from the fingers. In the last few days of pupal existence the movements are more frequent and vigorous, and usually the entire pupa is withdrawn from the crumpled larval skin before the period is ended. At the same time the pupa progresses anteriorly some 8 to 15 mm. from the position

occupied at the time pupation began. This progress of from 8 to 15 mm. was made in the soft wood pulp. In natural burrows the progress of the pupa as judged from positions in which early and late pupæ are found, is often greater and ends with the matured pupa projecting about one third of its anterior end from the surface of the wood. Usually the larval skin and head capsule can be found in the burrow from 5 to 10 mm. caudad to the empty pupa skin.

Only one specimen, of those placed between glass slides, whose change into a pupa was timed, survived the entire pupa stage and emerged. This was noted as a quiet and pale larva at 4 P. M., March 14. At 9 A. M., March 17, the faint outline of the pupal head and thorax were visible and by noon of the same day the larval skin was turned back as far as the wing pads. A female completed its emergence (free of the pupa skin) at 6 P. M., March 25.

The actual emergence of the adult from the pupa skin takes from 5 to 15 minutes. The head and thorax quickly appear after the initial splitting of the skin, but the abdomen and legs are slowly withdrawn by periodic rythmic rocking of the body backward and forward and by waves of expansion and contraction that pass caudad along the abdomen. Until the legs are free the emerging body projects vertically above the pupa skin, but once the legs are free of their sheaths, the body is bended over until the feet take hold of the surface of the wood and the rest of the abdomen is then smoothly withdrawn. In less than an hour the swollen and elongate abdomen assumes a normal size but full adult coloration and hardening requires about two hours. Flight is possible long before the abdomen has reduced to normal size, but if undisturbed the female rests quietly near the empty pupa skin until normal size is attained and considerable hardening has taken place. Frequently the maturing females are found by older males, and copulation takes place before the female is fully hardened and colored.

Descriptions of the Immature Stages.

The Larva (Full Grown).

Length 13 mm.; diameter at second thoracic segment, 1 mm.; at third abdominal segment, 0.8 mm.; at spiracular disk 0.9 mm. Form slender, very elongate, terete or but slightly flattened dorso-ventrally. The slight enlargements at the thorax and caudal end are abrupt. The integument is colorless and transparent save for a faint brownish cast in the thoracic region; thickly covered with an appressed, pale pubescence. In the living larva the massive, dark brown head capsule shows thru the integument and against this background the pubescence of the first thoracic segment has a hoary reflection. In life, the first six and a half body segments are colored a transparent lobelia violet* by the body fluids; in the seventh segment this color is displaced by chrome yellow, due to the fat bodies that show through. The chrome yellow continues posteriorly to a narrow band of lobelia violet just cephalad of the spiracular disk. When the larva moves the boundaries of these colors shift somewhat with each expansion and contraction. When killed the body coloration changes to a uniform, opaque, yellowish white. Narrow creeping welts extend across the tergites and sternites of the second to seventh abdominal segments, inclusive, just caudad of their cephalic margins. These welts are slightly elevated, especially at the mid-dorsal and mid-ventral lines, and bear three cephalic and two caudal rows of minute setae. The setae are appressed and those of the cepahlic and caudal rows point cephalad and caudad, respectively. The setae of the opposite inner rows are distinctly larger than those of the three (two cephalic and one caudal) outer rows.

The spiracular disk (Fig. 1 b), flat and squarely truncating the axis of the body, has a diameter slightly greater than that of the body. It is composed of four broad, petal-like lobes that divide the face of the disk into subequal quadrants, separated by narrow, pale lines. Each quadrant is dark chestnut brown, save for a narrow, pale border, at or near the outer margin of each quadrant. The extreme outer margins of the dorsal quadrants are dense blackish brown. The lower "quadrants" are larger than the upper, their angles extending dorso-mesad past the center of the disk. The spiracles are elongate elliptical, the inner ends dorsad to the lateral and separated by about half the length of one spiracle. They lie at the inner ventral margin of the dorsal quadrants. The entire arc of each quadrant-like lobe bears a close-set single row of long, stout, pale brown hairs that curve slightly cephalad; except at the middle of the arcs of the ventral lobes, where these hairs are shortest, they are about as long as half the diameter of the disk.

The head capsule (Fig. 1 a), is compact and massive. Its sides are formed by two mussel-valve-like, chitinized plates; the dorsum is a triangular chitinized plate, margined by two heavier rods of chitin

* Ridgway, Robert, Color Standards and Nomenclature, Washington, 1912.

whose divergent cephalic ends fuse with the lateral plates in areas of heavy chitinization, and whose convergent caudal ends are separated by a narrow cleft in the caudal end of the dorsal plate. The labrum is large, broad, semicircular posteriorly; clothed with long pale hairs; two widely separated papillæ, bearing several short hairs, are situated at about mid-length. Antennæ short; basal joint cylindrical, stout, with scattered long pale hairs; at its apex bearing a short, slender, elliptical second joint and several minute, slender papillæ. The mandibles (Figs. 1 d, 1 e) are heavily chitinized, dark brown, massive and comparatively large. At the apex of each mandible are two conical, blunt teeth, the ventral one the larger and curved ventro-mesad; the ventral margins bear four flattened, broad cutting teeth. The maxillæ are large, having the appearance of inflated sacks, and are bilobed distally. The mesal lobes are densely hairy on their inner faces; the outer surface of the mesal lobes and the entire surface of the lateral lobes are clothed with long pale hairs. The lateral lobes are more slender than the mesal and each bears near the apex of its lateral margin a short, broad, cylindrical palpus, that in turn bears a number of minute papillæ. The large mentum (Fig. 1 c) is almost entirely cleft from behind, the cleft ending just before the apex of the median tooth. On either side of the median tooth are four, flattened, triangular teeth, the median pair as large and extending as far cephalad as the median tooth, the three lateral pairs progressively smaller and more caudad. The two halves of the mentum are borne at the end of two chitinized bars that extend forward from the ventral margins of the lateral plates. The hypopharynx bears on the anterior margin of the anterior plate eight equal, small, rounded teeth. The posterior plate bears no teeth, that I can discern, but is slightly thickened on the anterior margin.

The Pupa.

(Fig. 2, a, b, c, e).

Length, males 8 mm.; females 10 mm. Diameters at the base of the wing pads, female pupæ; dorso-ventral, 1 mm.; dextra-sinistral, 0.9 mm. Male pupæ slightly smaller. Form very slender and elongate. From the maximum diameter at the mesothorax, the body tapers evenly toward the caudal end. Color: head and thorax buckthorn brown, with the wing pads, and eyes chestnut brown; the leg sheaths range from light orange yellow at their proximal ends to chestnut brown at the tarsi. The abdomen is a striking orange yellow, becoming dark reddish yellow late in pupal life. The head is small, slender; the eyes relatively large, in the male almost contiguous above and below, in the female separated by about half their width. The cheeks gibbous laterally, their latero-ventral angles prolonged and flattened. Labrum sub-quadrangular, slightly expanded before the rounded apex; labial lobes broad and blunt, their inner margins contiguous. Maxillary palpi conical, thick at the bases, the apices curved dorso-laterad to the ventro-laterad tips of the cheeks. Cephalic crest absent, this region a smooth rounded plate, lower than the bases of the antennæ. The

antennæ arise at the inner dorsal margins of the eyes, their basal two fifths stout and angulated, the distal three fifths more slender and with few angulations. Apices of the antennæ opposite the wing bases.

Thorax slender and almost cylindrical, except for the cephalic margin of the mesonotum, but slightly chitinized. The large, flat pronotal breathing horns extend slightly cephalad of the head and lie in approximately sagittal planes to the body. Each horn is triangular in outline, the line of insertion on the pronotum forming the acute but truncated apex of the triangle, the elongated distal margin of the horn forming the triangle's base. The lines of insertion of the two horns are parallel and are separated by more than a third of the width of the pronotum, but the dorsal and ventral angles of the distal end of the horns curve mesad so that their inner faces are concave. Along the entire rounded edge of each horn runs an irregular line of minute, unchitinized, rounded papillæ. No pores are perceptible. The mesonotum is elongate; its crest is unornamented but forms a rounded, chitinized edge that projects over the caudal margin of the pronotum. Wing pads narrow and elongate, ending just before the caudal margin of the second abdominal segment. Tarsal sheaths slender and elongate, ending opposite the cephalad half of the fourth abdominal segment; their apices level.

The abdomen with the integument very delicate; caudal margins of tergites and sternites slightly more heavily chitinized; tergites and sternites of segments three to six, inclusive, bear a row of minute, caudally directed setæ. Lobes of the eighth sternite not evident. Female cauda (Fig. 2 c) with the blunt conical sternal valves slightly longer than the tergal valves; the latter abruptly truncated. Male cauda with two dorso-lateral blunt lobes that project caudad and two much longer ventro-lateral lobes that extend dorsad between the dorso lateral lobes. Between the bases of the ventro-lateral lobes, a short rounded papillus projects caudad.

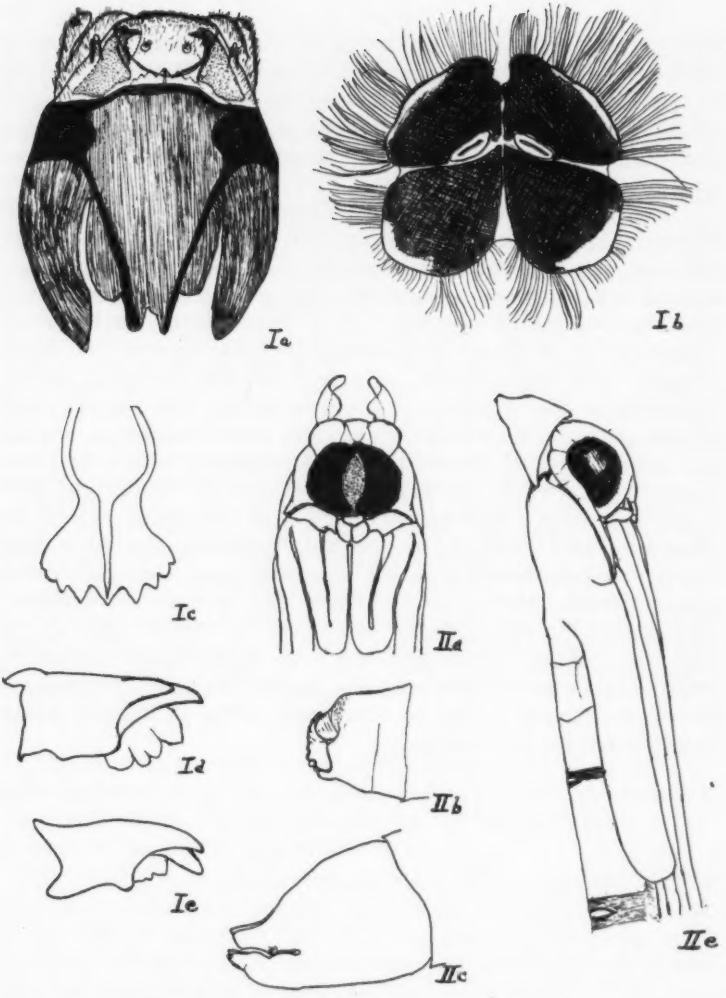
The above descriptions are drawn from about 50 larvæ and pupæ collected in Jefferson County, Indiana and in Alachua and Liberty Counties, Florida, now in the collection of Museum of Zoology of the University of Michigan.

On the basis of adult structure, Dr. Alexander has placed the genus Diotrepha, provisionally in his subtribe Antocharia of the tribe Limoniini*. In the structures of the pupa and, especially, of the larva, *Diotrepha mirabilis* shows a much closer apparent resemblance to Limonia than to Antocha. However, the habitat of the immature stages of *Diotrepha mirabilis* is very like the habitat of the immature stages of Limonia and is strikingly different from the habitat of the larva and pupa of Antocha which live, attached to stones, beneath the surface of

* Alexander, C. P., The Crane-Flies of New York, Memoir 38, Cornell Univ. Agr. Exp. Sta., Ithaca, N. Y., 1920.

flowing water. No doubt, much of the structural similarity between the immature stages of Limonia and Diotrepha is due to this close similarity of habitat and the entirely different types of habitats occupied by Diotrepha and Antocha necessitate the differences in mouth parts, respiratory organs and other structures.

In defining the subtribes of the Limoniini, Dr. Alexander took into account both adult and immature characters and held that the subtribes Antocharia, Limonaria and Ellipteraria are closely related. In spite of apparently very great differences in the larva and pupa of Antocha, they have many fundamental resemblances to those of Limona: general type of the head capsule and mouth-parts, structure of the creeping welts, character of the integument, the proportions and chitinization of the pupa. In view of the evident relationships shown by the adult stages of Diotrepha and Antocha, I believe that the similarity between the immature stages of Diotrepha and Limonia does not indicate so much that Diotrepha should be placed in the Limonaria, as that the Antocharia are very close to the Limonaria and that the pecularities of Antocha's larva and pupa are due to their unique (for a cranefly) habitat. Dr. Alexander has already expressed his belief that many structures of the larva and pupa of Antocha are adaptive rather than phylogenetic and the resemblances of Diotrepha's larval and pupal stages to Limonia's offers, I believe, some evidence for that probability.



Larva and Pupa of Diotrepha mirabilis Osten Sacken.

I a—Head capsule of larva, dorsal view.
I b—Spiracular disk of larva, caudal view.
I c—Mentum of larva.
I d—Mandible of larva, mesal view.
I e—Mandible of larva, dorsal view.
II a—Head of pupa, ventral view.
II b—Cauda of male pupa, scale larger than IIa and IIe.
II c—Cauda of female pupa, scale much larger than IIa and IIe.
II e—Head and thorax of pupa, lateral view.

THE HOST-SELECTION PRINCIPLE AS APPLIED TO BRUCHUS QUADRIMACULATUS FAB.

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One of the most interesting principles recently developed in economic entomology, if not one of the most far reaching in its application is the host-selecting principle. As defined by Dr. A. D. Hopkins(1) this principle is that an insect "species which breeds in two or more hosts will prefer to continue to breed in the host to which it has become adapted."

By carrying this principle to its extreme hypothetical conclusion we would have developed from the progeny of one polyphagus insect species, a great number of distinct species each in turn being monophagus. To use a specific illustration the progeny of a four-spotted cowpea weevil, *Bruchus quadrimaculatus* Fab., which had emerged from a blackeyed cowpea *Vigna sinensis*, if they by choice, accident, or by human manipulation were to breed in the chick pea, *Cicer arietinum*, the broad windsor, *Vicia faba*, or any one of a dozen other kinds of seeds, would become distinct species breeding in only one kind of seed.

In order to obtain more evidence relating to this principle the writer began a series of experiments in 1919 with Bruchids which normally breed in beans, *Phaseolus vulgaris*, and cowpeas, *Vigna sinensis*. These weevils offered material which was very well adapted to the conduct of such experiments. The four-spotted cowpea weevil, *Bruchus quadrimaculatus*, which in California breeds almost exclusively in blackeyed cowpeas but which is known to breed in many varieties of cowpeas and other seed, produces several generations each year thereby giving an opportunity to study the inherited tendencies.

* This article in a somewhat different form was a thesis presented to the department of biology, University of Southern California, in partial fulfillment of the requirements for the degree of Master of Science.

The writer wishes to express his thanks to Dr. E. A. Back and Dr. A. D. Howard for valuable suggestions, and to Messrs. P. Simmons, A. H. Amis and C. K. Fisher for painstaking assistance in examining the seeds and checking results in the experiments.

HISTORICAL.

Apparently very little work has been done on the adaptation of insects to their host plants or their variations due to their selection of host plants, however, the few references found are well scattered through European and American Entomological literature.

According to Craighead (2), Dr. Walsh (3) (4) is probably the first entomologist to state definitely this principle in concise wording. The following quotation (3) is taken from pages 405-406-407, Volume III:

"Even with the little we know of the Laws of Inheritance, we might infer a priori, that from peculiar circumstances a Phytophagic Variety, including both the sexes, has fed for a great many generations upon one paticular plant of the number inhabited by the species to which it belongs, it would be likely to transmit to its decendants in the imago state a tendency to select that particular plant upon which to deposit its eggs. We know, for example, that young pointer puppies when taken into the field, will frequently point game without any instruction or training whatever, though the habit of pointing is clearly acquired and not a natural habit, and must have been transmitted to them from their ancestors in virtue of the Laws of Inheritance. If then, it should happen that owing to the presence of but a single species of the plants ordinarily fed upon by a particular species of insects, or to other causes, eggs have been uniformly deposited by a Phytophagic Variety upon the same plant for an indefinitely long series of generations—say fifty, or a hundred, or a thousand—and the female has in no case intercrossed with a male belonging to a different Phytophagic Variety, then it is probable that habit will have become a second nature, and that it will cease to be possible for that insect, which by the supposition has fed upon that one plant for a very long series of years, to feed upon any other plant than that to which it has become habituated by the Laws of Inheritance.

"But before this point is reached, another series of phenomena will have come into play. Every naturalist is aware that species often run into what are known as geographical races, when separated into two or more distinct groups by physical barriers. Just so the Phytophagic Variety, having by the supposition been isolated from the other members of its species, will often run into what may be called Phytophagic Races, and finally, perhaps, acquire a moral indisposition, or a physical inability, to intercross with the other members of the species. It will then have become what I propose to call a Phytophagic Species, distinguished from the other members of the species to which it originally belonged by certain slight peculiarities of size, or of coloration, or occasionally even of structure, just as geographical races are so distingiushed. But there will be this essential difference between the two cases: Geographical Races are connected, or supposed to be

connected, by all the intermediate grades, and may therefore be reasonably concluded to intercross on the confines of their geographical boundaries. Phytophagic Species are not so connected, and by the supposition they do not intercross, or, at all events, only in very rare instances, as is sometimes the case with what are allowed on all hands to be distinct species.

"According to my views, Phytophagic Species are as truly distinct species as those which differ by much stronger characters. 'The only valid practical criterion,' as I have already said, (Proc. Ent. Soc. Phil. II, page 220) of specific distinctnes is the general non-existence, either actually ascertained or analogically inferred, of intermediate grades in the distinctive characters, whence we may reasonably conclude that the two supposed species are distinct, i.e., that they do not now, in general, mix sexually together, or if geographically separated, that they would not do so, supposing them to be placed in juxtaposition."

He substantiates these statements by many careful observations in nature as well as by experiments on several species. In this connection he says,

"Hence, we may conclude, first, that *tessellaris* may, without very material injury to its health, be shifted on to Oak from other trees on which it naturally feeds: for although, of those that were retained on oak, a much larger percentage spun up than of those that were shifted on to oak from other trees, yet a considerable percentage of the former, and none whatever of the latter died in confinement. Second, that sycamore is not a congenial food for *tessellaries;* for a considerable percentage of those fed on sycamore died in confinement, and a small percentage spun up. Third, that oak is adhorrent to *Harrisii* as a food plant. It may seem strange at the first view, that *tessellaris* can be compelled to feed upon sycamore up to the time of its assuming the pupa state, and *Harrisii* cannot be compelled to feed for any length of time upon oak; but when we consider that in a state of nature the former is polyphagous and the latter monophagous, our surprise will cease. It is not that *Harrisii* does not eat the oak leaves furnished to it—for the quantity of excrement on the floor of the breeding-cage at each shifting and cleaning out proved that it must eat them—but that having eaten them, it either perishes of disease superinduced by the unnatural food, or bores its way out in despair through the millinet of the cage, or devours its own brethren in default of its natural food-plant."

More than 50 years later while working without knowledge of Walsh's investigation or conclusions, Craighead found that some species of wood boring beetles acted very much as those mentioned above. Of *Cyllene pictus* he writes (5),

"The larvæ of *Cyllene pictus* feed almost exclusively in hickory. A few specimens have been taken in wild grapevine (*Vitis sp.*), mulberry

(*Morus rubra Linn*), osage orange (*Toxylon pomiferum Raf.*) and hackberry (*Celtis occidentalis Linn.*), but such instances are rare and of very local occurence. In one locality near Harrisburg, Pa., all except one of these unusual food plants have been recorded. This borer is found generally distributed east of the Mississippi River."

After describing several experiments with this insect on host selection and adaption he concluded that "This species, although most commonly found in hickory, will readily adapt itself to several other plants, notably mulberry and grape, both of which are recorded as natural hosts.

"In some unfavorable hosts, or in an optimum host in an unfavorable condition, the larvæ may become established, but the mortality is high and the progeny seem to be sterile."

"*Neoclytus capraea.*" he says, "is known to inhabit the eastern and central western United States, extending its range south and west into Arizona. It has been recorded from only two hosts, ash (*Fraxinus*) and white oak (*Quercus alba* of the Rocky Mountains). In the eastern United States it has never been found in oak." This is followed by observations of this insect's habits in nature as well as by descriptions of several carefully executed experiments after which he concludes, "The foregoing experiments show that this species feeding in ash (*Fraxinus*) has become decidedly accustomed to that host.

Several attempts, both by oviposition and larval transfers, to produce strains in *Quercus alba* Linn. and *Hicoria* have resulted in failure. In *Hicoria* the few adults secured were incapable of continuing the colony, and in both woods a high or total mortality occurred.

"Even with this decided preference for a host, the adults laid eggs on a new host rather than on an unfavorable cut of the normal host."

Speaking of *Molorchus bimaculatus* he says, "a very decided predilection for the orignal host is exhibited by the host strains of this species. It is not surprising in the case of the hackberry form, as this is the only host from which it has been found. However, this form would not even lay eggs on any host other than the orignal."

On page 411, Volume III, Walsh (3) writes as follows: "That there may be no mistake, it may be as well to say here that the difference between what I call a Phytophagic Variety and what I call a Phytophagic Species is simply this: The former habitually intercross with the normal race, and the latter do not."

Craighead noted the fact that several species in his experiments, after having bred in the same wood two or three years did not copulate as readily with other strains as did those from the same plant.

After years of careful experimenting with certain cerambycid beetles Craighead (5) summarizes his results as follows:

1. In practically all the species experimented with the adults show a marked predilection for the host in which they have fed as larvæ, provided they are not deterred by other factors, such as the unfavorable condition or the small quatnity of the host.

2. There is considerable variation in the degree of preference for the orignal host, as between different species. Thus—
   (a) Certain species are capable of living in only one genus or species of plant, which consequently they select.
   (b) Certain species, chiefly those living in nature in several hosts, can be forced to adopt a new host.
   (c) Certain species, chiefly those feeding in nature in a great variety of plants, show little discrimination in the selection of hosts.
   (d) Certain species feeding in nature in a great variety of hosts often show preference for a few of these.
3. In forced transference of individual adults of a species to a new host, a high mortality of the brood usually occurs, especially in the case of eggs laid by beetles emerging from the original host, in which case the mortality is often total. One-half to full-grown larvæ, however, usually can be successfully transferred to a new host and live and transform to adults.
4. With some species that can be reared in a secondary (new) host, by the larvæ feeding one or part of one year, preference for that host is shown by the resulting adults.
5. In general, the fewer the hosts in nature, the more marked the predilection for a particular host and vice versa.
6. Continued breeding in a given host intensifies the preference for that host.
7. The condition of the host has a great influence on host selection, in that every species prefers an optimum condition of the host which it selects and will choose a new host in the optimum condition in preference to an old host in which conditions are unfavorable.
8. The quantity of wood at the disposal of the ovipositing adults may influence the insects in their choice between different kinds of host wood, in that, if there are many adults to a limited amount of the primary host, some species will select a secondary host if such is available. If this is done, however, the resulting brood is weakened.

"It is altogether possible that these experiments may indicate the origin of certain closely related species or varieties of insects. For instance, a species restricted to a very few plants may accidentally be forced to take a new host (as actually happened in the experiments with Cyllene in oak). A few individuals may survive and continue the strain so that it becomes after a time, at least physiologically different and may also develop correlated differences of colors or structure. It can hardly be said that such forms are much less distinct than in the case of the two species *Callidium antennatum* in pine and *C. janthinum* in juniper; for even though these have a slight color distinction and each is absolutely restricted to its own host, they interbreed. On the other hand, in the different forms of *Hylotrupes ligneus*, of which the eastern form in juniper is constant in marking, the western form in redwood is quite variable, as is also the Rocky Mountain form in Douglas fir. The juniper and redwood forms interbreed, but all attempts to mate either of these with the Douglas fir form have failed. All these

forms can be furnished with substitute hosts, but in the experiments in which this has been done the orignal color pattern has resulted thus far.

"The grape and hickory strains of *Cyllene pictus*, although showing no color differences, do not readily mate. Two species of Cyllene, *C. Pictus and C. robinae*, are separable only as adults, by a slight difference in the color pattern, yet in seasonal and biological habits they are strikingly different. It is conceivable that one of the two species originated through the adoption of a new plant and continuous breeding in that plant.

"It may be asked, If one or two years' feeding in a new host results in individuals which prefer that host, thus giving rise at least to new physiological varieties, why does not this occur more frequently in nature? That it does occur must be granted, as we have species living in many host plants as well as those restricted to a species or genus, but that it is not of common occurence is believed to be due to the high mortality in first-stage larvæ in a new host rather than to absence of oviposition in the new host. Although the adults show decided predilection for a favored host in oviposition and even, in certain species, a preference for the plants in which the larvæ have fed for one or two generations, the instinct to oviposit seems to overbalance that of host selection, consequently new hosts are frequently selected—possibly more frequently in nature than is generally realized. As an example of this, take *Cyllene pictus*, requiring hickory cut during the winter. This condition would be fully met in tops left during logging operations. When the timber cutting ceased, a concentration of adults would be left with none of the favored host plant available in the right condition. The grape, osage orange and hackberry strains collected at Hummelstown, Pa., were in reality taken in woods which had been logged for hickory and in which operations had ceased three years prior to the finding of these strains. At Falls Church, Va., in June 1920, adults of *Neoclytus erythroceaphalus* were observed on pine logs. Much infested ash, from the previous year, was lying about from which they had emerged in great numbers."

Bellyea (6) after experimenting on the control of White Pine Weevils, *Pissodes strobi*, by the use of mixed plantings of white pine and Scotch pine concludes that "The use of Scotch pine with white pine in mixed plantings under the conditions described in this article has reduced the amount of infestation in the white pine by almost 40 percent." Under the conditions of his experiments as reported this weevil breeding in a natural growth of white pine, infested the new plantation of Scotch pine more readily than the new plantations of white pine. This together with other data which he gives, indicates that this insect was influenced, in its choice of plants upon which to oviposit, as much or more by other factors, than by the inherited tendency to breed in its natural or original host.

Pictet (7) has shown by several examples that caterpillars of the second and third generation may be made to change their preferred food plants and that the adults reared from them exhibit changes in size and coloration. Corresponding observations were made by Schroder (8) who in a previous article (9) had showed "that even nidification (in *Gracilaria stigmatella F.*) and habits of feeding, combined with changes in reproduction (in the beetle *Phratora vitellinoe L.*) can be changed and that these acquired characters are transmitted spontaneously from the third generation."

In 1907 and 1908 Marchal (10) succeeded in transferring (5) numerous specimens of *Lecanium corni* Bouche from the peach (*Amygdalus persica* Linn.) to the black locust (*Robinia pseudacacia* Linn.). Eggs hatched and larvæ developed on the new host plant, spreading out over the leaves in large numbers, and in the fall migrating from the leaves of the wood for hibernation. In the summer of 1908 the insects completed their development and had then the large size, deep coloration, and characteristic appearance of the insect described by Douglas as *L. robiniarum*, the attack of which on the black locust had been severe in several European localities. This indicated that *L. robiniarum* was only a race of *L. corni*, resulting from individuals that had become transferred in some manner from the peach to the introduced American black locust. Dr. Marchal found great difficulty in reestablishing on the peach individuals of *L. corni* produced on the black locust.

With reference to the adaptability of certain lepidopterous larvæ, Dr. Brues (11) writes as follows:

"It has been claimed that the food habits may be modified experimentally, in that caterpillars reared on a strange plant (where they could be induced to select it) gives rise to moths whose progeny more readily accept the new plant. It is very difficult to accept such evidence, at least as having any general application, without very clear and incontrovertible proof. If such transformations can occur so easily and become hereditary so quickly they would have entirely destroyed the coherent habits now existent, during the enormous period which has elapsed, for example, since the violet-feeding Argynnids were differentiated, since the holarctic and nearctic Vanessids have been separated, or while the world-wide Aristolochia feeding Papilio were attaining their present distribution. That such a change has actually occurred in the case of other groups seems equally evident, although, as has been shown, we can more easily believe that they may have arisen through mutations in maternal instinct not incompatible with larval tastes and then only in extremely rare cases and confined to certain groups."

That the host selection principle is operating with Anopheles mosquitoes is claimed by certain writers. E. Roubaud (12-13)* points out that *A. maculipennis*, the chief malaria carrier of northern and central Europe, has come to prefer domestic animals to man; it has become "zoophilic" even to the extent of a change in the maxillary dentition; and this change in the blood-seeking habits of the *Anopheles* has been a large, if not the chief factor in the diminution or disappearance of malaria from certain well-populated regions of Europe, even in the presence of an adequate number of *Anopheles*.

In his "Mosquito Observations in Different Countries During the Past Three Years," Dr. Howard (14) says:

"Wesenberg Lund (15), in 1921, published a very important paper on the biology of the mosquitoes of Denmark, and thinks that the change pointed out by Roubaud has occurred in the last century; that formerly this malarial mosquito was mainly dependent upon human blood and that it has become almost exclusively an attacker of domestic animals, especially pigs, over most of Europe north of the Alps."

He also shows that various writers in Germany, Spain, Algeria, Albania, Sumatra and elsewhere have become convinced that domestic animals have been very prominent factors in protecting people from the ravages of malarial mosquitoes. The inference by at least part of these writers, is that the mosquitoes are changing their habits.

On this phase of mosquito activity, Barbar and Hayne (16) of the United States Public Health Service write the following:

"Our observations indicate that of the *Anopheles* mosquitoes common in this country, *A. qudarimaculatus* and *A. crucians*, at least show no special predilection for domestic animals over man when such factors as size and amount of exposure are excluded. The conditions which Roubaud describes as obtaining in France are not present in this country, at all events not in the Southern States. In the milder climate of these States many domestic animals roam at large in pastures night and day, summer and winter; stables are often of an airy construction and are rarely built immediately adjacent to human dwellings. Domestic animals may act as "buffers" in that they satisfy mosquitoes that otherwise might have fed on man, but there is little evidence that the *Anopheles* of this country have become zoophilic in the sense of Roubaud, or that they are likely to become so. It is questionable

*The structural change is open to verification and recent papers by Sergent and by Shannon cast doubt upon Roubaud's conclusions, which by the way, have been critised by Martin and others. (See L. O. Howard's paper on "Zoophilism with Anopheles," Journal Parasitology, Vol. X, pp. 191–98, 1924.

whether the increase in animal industry, apart from drainage and other concomitant improvements, has been a large factor in the decrease in malaria which has occurred in many parts of the United States. It is unlikely that a cordon of stables could afford much mosquito protection to dwellings, even if such a cordon could be maintained.

"So far as the results of one experiment indicate, one would not expect that a feeding on a domestic animal would affect the subsequent susceptibility of *Anopheles* to malaria parasites."

The sugar beet nematode *Heterodera schachti*, according to Capus and Marchal (17) may become adapted to other plants to the exclusion of their chief food plant. They say:

"That, by virtue of the conditions of pea culture in the Gironde, a race of *Heterodera schachti* was found especially adapted to peas and to the attack of which beets are resistant up to a certain point."

This is substantiated by other writers.

Nillson-Ehle, (18) writing of experiments conducted in southern Sweden on the resistance of certain barley varieties to *Heterodera schachti* says:

"Another consideration is the fact that *Heterodera Schachtii* also attacks sugar beets and other crops. Beets were never attacked by the barley strain of the organism, indicating biological strains of the organism, showing preference for particular hosts. It is probable that both strains occur together in the soil, and that if a crop of one host is grown in successive years, its particular strain will multiply. This explains the increase in infection in successive years after a crop of the other host. Another possibility is that there is a strain capable of attacking both hosts."

Thorne (19) in the U. S. Bureau of Plant Industry, writing of this same species, says;

"My own observations on *H. schachtii* lead me to believe that there is a ready change made from certain weeds, notably mustards, *Chenopodium* and *Atriplex* to sugar beets. Of this I am reasonably certain since fields which have been out of beets for 10-14 years have been reinfested the first year beets were again planted. However, I do not doubt that certain strains do become rather permanently adapted to certain crops."

Other records show the acquired adaption of certain species to new host plants. The practical application of such phenomena in economic work, apparently, has first been recognized by Dr. A. D. Hopkins (5) who made use of it in control operations conducted against the moutain pine beetle *Dendroctonus monticolae* Hopk. attacking areas of yellow pine (*Pinus ponderose*) along the Pacific Slope.

General Application of the Principle.

In a letter (20) to the writer, Dr. Hopkins says, "I feel confident that this principle will be found to have a broad application in economic entomology but we must expect to find some striking exceptions which, however, if not too numerous may prove the rule."

If this principle is found to have a wide application in entomology it will probably be found to be applicable to other branches of zoology. Many problems in parasitology may possibly be solved more readily in the light of the host-selection principle. It may even assist in solving problems of racial and individual immunity as well as the formation of new species.

Before this principle can be termed a rule in economic entomology very much more work will have to be done with many species of insects having widely differing life histories. A principle that applies to certain wood boring beetles and leaf eating caterpillars may not apply to certain other groups such as leaf hoppers and insects attacking stored products.

Some insects are known to feed in nature on a great variety of host plants while others are restricted to relatively few hosts. Experiments conducted at the Gipsy Moth Laboratory (21) show that of the many plants tested a decided variation was found in regard to the susceptibility to attack by this insect *Porthetria dispar*. The plants were divided into four groups; I, favored species; II, favored food species after early stages; III, species on which a small proportion may develop; IV, species that are unfavored food. These results show that, although this insect has a wide variety of hosts on which it is capable of feeding, certain ones are selected in preference to others in the natural forests. Just as great variation undoubtedly exists with some other miscellaneous feeders. It is conceivable even, that certain species may be held in check to a great extent by the choice of unfavorable hosts for oviposition, or the selection by the young stages, of hosts which are unfavorable for later development.

The codling moth, *Carpocapsa pomonella*, in nature has been restricted to comparatively few hosts. When it was first found to be working in English walnuts, *Juglans regia*, it was thought to be another species. However, numerous observations have shown that the moth lays its eggs rather

promiscuously on a great variety of plants as well as on various parts of the plants. Professor Quayle, (22) whose extensive experiments with this insect have not been published, says:

> "The codling moths that were reared from the apple oviposited equally freely on walnut and apple, as well as on pear and some other fruits that were in the same cage. Codling moths from the walnut also oviposited equally freely on the same fruits, apparently showing no discrimination. In the case of the walnut tree covered with cheese cloth the same facts were true, excepting that the larvæ upon hatching showed some preference for the apple over the walnut, that is, some of the larvæ that hatched from eggs on the walnut made their way over to the apple which they entered.
>
> "In other words, so far as my experience goes, there was no indication of different species or varieties but that their habits were identical whether bred from the apple or from the walnut."

While the larvæ of the codling moth show some preference for apples it seems that this tendency is not transmitted to the adult neither does it appear that breeding in one host has any influence in causing the choice of that host for oviposition. It is probable that the larvæ are able to penetrate the apple with greater ease or that the apple offers greater protection while effecting their entrance. In an orchard where apple and walnut trees alternate this slight preference would be of no importance because it would be practically impossible for the young larvæ on the walnut trees to reach the apple trees therefore in an orchard of this kind the only possible selection would be made by the adult. Copulation appears to occur as freely between insects having bred in different hosts as with insects having bred in the same host. So far as present knowledge goes, there is no indication that the host selection principle will hold with the codling moth.

Work with the Hessian fly, *Phytophaga destructor* indicates that with an abundance of food available it will breed on several plants with preference shown for certain plants (23). While sufficient data has not been accumulated to justify a definite conclusion, it appears probable that resistant varieties of grain may be developed, and that "strains" of Hessian fly breeding on single species of plants do not develop.

If there is any large group of insects in which this principle will not hold, it will undoubtedly be with those injuring stored products. Among these may be included some species of lepidoptera and many species of coleoptera. Although the

writer has no tabulated data, his work with bean weevils, has called him into warehouses throughout California and other states and has given him an opportunity to observe these insects under varying conditions.

The rice weevil, *Calendra oryza*, which in India was a pest in rice, breeds freely in the United States in wheat, corn, oats, barley, sorgum, kafir, buckwheat, rice and sometimes in flour and meal if they become caked. The writer's observations indicate that this insect does not produce "strains" or "phytophagic species" but that copulation takes place freely between individuals having bred in different hosts. In mixed grains such as some of the scratch feeds for poultry this insect appears to work indiscriminately generation after generation.

In speaking of the Indian Meal Moth *Plodia interpunctella*, Dean (24) says,

> "This insect feeds on edibles of almost every sort, such as meal, bran, flour, grain, breakfast foods, dried fruits, roots, seeds, nuts, etc. It will attack dried insects, herbariums and other museum specimens. It has even been taken in bee hives, where it was working upon the comb, or wax."

The writer's observations on this insect indicate that it shows no tendency towards the development of strains manifesting a preference for the host from which they bred.

Numerous other insects of economic importance in this group might be cited whose tendencies do not point toward the development of new species by way of the host-selection principle, but rather point towards a wider range of materials upon which to perpetuate the species.

An interesting example of an insect of no apparent economic importance adapting itself voluntarily to new conditions thus making it a potential menace has been observed by the writer. The insect *Bruchus pruninus* has been known for years to breed only in acacia seeds. During the summer of 1920 the writer grew beans of different varieties near some acacia trees, *Acacia melanoxylon*, in which the seeds were infested with this weevil *B. pruninus*. After harvesting the beans they were kept for observation in connection with the work on *Bruchus obtectus*. From some California pink beans a few very small weevils emerged. At first they were thought to be *B. obtectus* which had failed to develop normally in size and color but when several of them emerged they were determined by J. C.

Bridwell as *B. pruninus*. In 1921, the writer grew another crop of beans in another locality near the same species of acacia trees. That year *B. pruninus* emerged from soy beans, *Glycine hispida*, red Mexican, California Pink, and Early Refugee beans, *Phaseolus vulgaris*. In neither of these cases was the insect forced, because of scarcity of food or because of the food being in an unfavorable condition to oviposit on the cultivated plants. The writer bred them in the soy beans in storage four generations. After four generations they were killed by mites, *Pediculoides ventricosus*, before the writer had an opportunity to determine whether or not they showed any predilection for soy beans or for acacia or whether they would mate freely with those breeding in acacia seeds but as far as his observations went there was no difference in size or color.

As there are many varieties of beans grown in California near acacia trees, which as far as the writer has observed are infested with this weevil, it would be very likely that every year some beans become infested with this weevil. It would also seem quite probable that if it inherited tendencies in accordance with those presupposed in the host selection principle, it would have developed a strain of weevils living only in beans of the same variety and that it would have attained some economic importance. The writer however, has been unable to find that any one else has even observed it breeding in beans.

It appears that in nature this insect oviposits on new hosts even in the presence of abundant material of the normal host or the host in which it had bred. It also seems that weevils emerging from new hosts do not become established thereon, but return to the primary or original host.

Experiments and Observations on *Bruchus quadrimaculatus* Fab.

Bruchus quadrimaculatus Fab. is found wherever cowpeas are grown extensively. Because of the great damage it does to the crop together with the added labor and expense it causes, its importance is very great. In some sections farmers have discontinued growing cowpeas because of the heavy loss due to the ravages of this insect. Frequently the entire crop, which at the time of storing shows no apparent weevil injury, in a

short time is a total loss. With blackeyed cowpeas and probably with other varieties this loss is caused not only by the number and amount of the seeds actually devoured but by the mold and decay, which as has also been pointed out by Chittenden (25), Swenk (26), and others, usally follows more promptly the attack of this weevil than of any other.

The following is only one of the many examples of the heavy losses caused by the four-spotted cowpea weevil, *B. quadrimaculatus*. One car load of blackeyed cowpeas, after passing inspection in Los Angeles, was shipped to Georgia. The car was less than a month in transit, but on arrival at its destination it was found to contain 300 bags so badly weevil damaged that they were a total loss.

It would be impossible to give an accurate estimate in dollars, of its injury in the United States, because not only do the production and price of cowpeas vary from year to year, but the actual weevil injury also varies from year to year.

In California its chief food is the blackeyed cowpea, but the writer's observations indicate that it thrives equally well and shows little if any preference for any variety of cowpeas, *Vigna sinensis*.

Paddock and Reinhard (27) record having bred it from the following varieties of cowpeas: blackeyed, old Bokhara, Chinese red, Chinese yellow, red ripper, iron, speckled cowder, whippoor-will, tinkles Holstein, new era, and lady pea.

They say, speaking of *B. quadrimaculatus*, "The cowpea weevil has not been observed to feed upon any plant except the cowpea—it is doubtful if any other plants can be added to the cowpea as a food for this insect." Speaking of its adaptive capacity they say, "There is a very little flexibility in the habits of this insect to adapt itself to a strange environment. This is particularly true with respect to its food plant. Changing the food from one variety of cowpea to another did not apparently affect the weevil, but when a nearly related food plant, such as certain varieties of beans, navy, and lima, were repeatedly tried, the weevil would not complete its life cycle. In all experiments egg deposition took place readily enough, as has been elsewhere stated. The eggs hatched in a large percentage of cases, but the larvæ could not subsist in the substituted food, and all were dead within three days after hatching. In the field the cowpea weevil has not been collected consistently on any plant except cowpeas. When the food is removed the weevils probably disseminate from that point to other patches of cowpeas, instead of attacking other plants growing adjacent to infested patches. The weevil is restricted to the cowpea as a food plant."

Writing of the same insect, Pettit (28) says, "It will also feed on table beans on occasion," and later he adds (29), "It also works in the common bean and like the common bean weevil it works indefinitely in the stored seed until nothing of value is left. Like the bean weevil, this creature starts work in the field, coming into the granary with the harvested beans, or it may gain access after the beans have been stored away."

Back and Duckett (30) say, "Peas and beans of many varieties are attached."

Skaife (31) working in South Africa in 1918 reported that they "Oviposit freely on peas and beans, but I have not succeeded in rearing any in these seeds. The eggs hatch normally and the young larvæ burrow into the seeds, but they all die without attaining any size."

Bridwell (32) in Hawaii the same year, says, "I have bred it (*Bruchus quadrimaculatus*) experimentally from *Phaseolus lunatus, P. articulatus, P. aureus, P. acutifolius, Dalichos lablab, Vicia faba,* and *Pisum satavum.*"

SCOPE OF THE EXPERIMENTS.

The above records make it quite apparent that the same results have not been obtained either naturally or experimentally in different localities. The writer, therefore, has been carrying on experiments for 5 years to determine the possible range of host plants as well as its tendencies toward the development of strains becoming adapted to certain host plants.

These experiments have been carried on at Alhambra, California. Seeds of numerous kinds as are shown in the following tables were used. Counted numbers of seeds of various kinds, sometimes alone and sometimes mixed, were placed with counted weevils of known age, in glass containers, Mason jars, or glass vials, where they could be carefully studied. Their habits and length of life were recorded as were the numbers of eggs laid on each individual seed as well as the total number of eggs on all the seeds. Hundreds of records of individual weevils and their progeny have been made. Table 1, shows a typical record of a pair of weevils and their progeny. In this instance the eggs were laid on blackeyed cowpeas. This particular record is taken because it illustrates the possibility of an infestation, which occurs at, or immediately after harvest, being carried several months without becoming apparent to the casusal observer. Had the record begun at the beginning of warm weather instead of the beginning of cold weather, the record of emergence would have been complete in from 27 to 42 days instead of from 98 to 132 days, or in other words, a gener-

ation would have been complete in a month or six weeks instead of three to four and one-third months. The table is also typical in showing little or no difference in the rate of development of males and females emerging from eggs laid on the same day. The first and last emerging weevils may be of either sex.

TABLE 1.

Record of one pair of *Bruchus quadrimaculatus* Fab. and their progeny (first generation)* showing the minimum, maximum, and average duration in days of the life cycle of all the weevils, the males and the females from each day's eggs.

Weevil Number	Date of Oviposition	Number of Eggs Oviposited	Number of Eggs Hatched	Number ♂ Emerged	Number ♀ Emerged	Total Number of Weevils Emerged	Minimum Number Days Required	Maximum Number Days Required	Average Number Days Required	♂			♀		
										Minimum	Maximum	Average	Minimum	Maximum	Average
11	9/20	21	16	8	6	14	98	130	111	100	129	114	98	130	107
....	21	11	9	1	5	6	102	132	117	132	132	132	102	127	113
....	22	13	12	6	4	10	104	126	111	104	126	111	107	115	111
....	23	12	11	4	6	10	99	117	107	99	117	107	99	117	108
....	24	12	11	5	4	9	103	124	114	104	124	113	103	123	115
....	25	7	4	1	3	4	116	126	121	121	121	121	116	126	121
....	26	14	11	4	6	10	115	127	122	118	126	122	115	127	122
....	27	1	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
....	28	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
....	29	1	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
....	30	1	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total.....		93	74	29	34	63	98	132	114	99	132	114	98	130	113

* Preoviposition period was less than 1 day. ♀ died the day of the last oviposition record.

It is impossible to say definitely how long this weevil has been in California, but the writer has examined specimens taken in widely separated sections as early as 1913. In some sections where it has caused serious losses, it has, for 10 years or longer, had only one host plant, the blackeyed cowpea. During this time at least 50 or more generations have developed in the same host.

Early in 1919 the writer having only weevils which had bred 50 or more generations in blackeyed cowpeas, placed them in containers with the following varieties of common beans, *Phaseolus vulgaris*, Mexican red, pink, Lady Washington, and blackeyed cowpeas, *Vigna sinensis*. After daily observations as to the variety of beans on which it preferred to oviposit, he concluded that with these beans its choice was in the following

order; first, Mexican reds, second, pinks, third, blackeyes, and fourth, Lady Washingtons. Because of this preference for the Mexican reds and also because the eggs could be seen most easily on that variety, it was used almost entirely for making daily records of the number of eggs deposited by a series of females during their lives. As a result, eggs were laid on all varieties but principally on Mexican reds. All the eggs were put together in one container for each day. Towards the latter part of the series only Mexican reds were used. Between July 7, and 25, 5718 eggs were deposited; of these 2661 were on Mexican reds having no other variety among them. Of the other 3057 eggs, the majority were on Mexican reds. From all these eggs 358 weevils emerged from the blackeyed cowpeas. About two-thirds of the eggs on the blackeyed cowpeas produced adult weevils, while not a weevil emerged from the other varieties of beans. In the varieties other than blackeyes, the tiny larvæ usually died immediately after boring through the testa or seed coat, but in some instances they were able to make a perceptible cavity in the cotyledon before they died.

EXPERIMENTS TO DETERMINE HOST PLANTS.

In an effort to determine the possible range of host plants among the seeds available at the laboratory in 1920, several pairs of weevils were placed in vials containg the following varieties of seeds:

Large white limas *Phaseolus lunatus macrocarous.*
Henderson bush or baby limas *P. lunatus.*
Tepary *P. acutifolius.*
Scarlet runner *P. multiflorus.*
Velvet bean *Stizolobium* sp.?
Castor bean *Ricinus communis.*
Lentils *Lens esculenta.*
Soy bean *Glycine hispida.*
Yard long or asparagus bean *Doliches sosquipedalis.*
Chick pea *Cicer arielinum.*
Broad windsor *Vicia faba.*
Two varieties of cowpeas *Vigna sinensis.*
Twenty varieties of common beans *Phaseolus vulgaris.*

Eggs were deposited freely on all varieties of seeds but emergence occurred from only two varieties of cowpeas, the broad winsdor, chick peas, yard long, soy beans, and lentils. On all of the other varieties the eggs hatched normally but the larvæ died before they had wholly entered the cotyledons.

The foregoing seeds had been purchased on the market with no way of determining how old they were or whether they had been fumigated.

Experiment 2.

In order to determine whether or not the age of the beans might have some influence on the ability of the larvæ to subsist within them the following freshly harvested varieties were used and the results compared with those obtained by using the same varieties one or two years old.

1. Tepary
2. Baby lima
3. Pink
4. Small white
5. Bayo
6. Cranberry
7. Refugee Green Pod
8. Brown Kentucky Wonder
9. Mexican Red
10. Red Kidney

Numerous eggs were deposited on each sample and the same results were obtained from all these varieties, from the newly harvested beans and from the old ones. All larvæ died soon after hatching, many of them having penetrated through the seed coats of each variety.

Experiment 3.

That the young larvæ might more easily penetrate the beans the following varieties were tried after being moistened as well as in their dry condition.

1. Baby limas
2. Teparys
3. Pinks
4. Navy
5. Pinto
6. Bayo
7. Cranberrys
8. Brown Kentucky Wonder
9. Refugee Green Pod
10. Mexican Red
11. Red Kidney

Oviposition took place as freely on the dry as on the moist beans. The eggs hatched normally in each case but the larvæ died before penetrating to any depth, although it is generally conceded by entomologists, bean-growers, and dealers alike, that moist beans furnish ideal conditions for the development of weevils.

Experiment 4.

Weevils were allowed to oviposit on the following varieties of beans after all of their seed coats had been removed except a small area which was left for identification.

1. Limas
2. Baby limas
3. Pink
4. Small white
5. Large white
6. Bayo
7. Cranberrys
8. Brown Kentucky Wonder
9. Refugee Green Pod
10. Tepary
11. Red Kidney
12. Mexican Red

Eggs appeared to be laid as freely on one part of the beans as on any other, they also hatched as well on one part as on another, but in no case did the larva enter the bean more than a short distance before it died.

The above experiments seemed to indicate that under local conditions at least, this weevil was unable to develop in the following: *Phaseolus lunatus P. acutifolius, P. Lunatus macrocarpus, P. multiflorous, P. Vulgaris,* (twenty different varieties), *Stizolobium sp? Ricinus communis.*

These experiments indicate that, the age of the bean, the moisture content, and the thickness of the testa, are not prohibitive factors in the development of the larvæ. They show that the minute larvæ can penetrate into the cotyledons of any of these beans, even those having such thick hard coverings as that of the lima, Italys Favorite, the velvet bean, the broad windsor or horse bean, or even the castor bean. Figure 1 shows (a) eggs on horse bean (b) eggs removed to show entrance holes, (c) seed coat removed to show the depth of penetration. The weevil can breed in this bean.

The ability of the tiny larvæ to penetrate to their food is further emphasized by the fact that they can readily bore into painted lead pencils and varnished handles of disecting needles. They have made appreciable cavities in the black paint or enamel on an iron ring stand where the eggs had been deposited in the laboratory. Figure 2 shows eggs of *Bruchus quadrimaculatus* on lead pencils (Dixons No. 3 and No. 6 H) and the varnished handle of a dissecting needle also the depth to which some of the larvæ burrowed.

At Tucson the Plant Breeding and Agronomy Department of the University of Arizona, had a great many varieties of seeds in a store room where weevils had access to the various seeds. These were contained in laboratory jars and sacks and had been fumigated, but had been reinfested. Some of the jars contained stoppers while others did not. There was evidence to indicate that weevils had had access to almost all of the seeds at some time. While the Angoumois grain moth

and some of the grain weevils were present, the insect most in evidence and the only Bruchid observed was *B. quadrimaculatus*.

I examined those seeds very carefully, and dissected many of each variety where eggs of *B. quadrimaculatus* were present. The following list gives the varieties of seeds and the number of samples of each variety in which I found the above weevils breeding:

Warshaver field peas *Pisum sativum* (2 samples),
Colorado stock peas,
Early Ramshorn blackeyed cowpeas *Vigna sinensis*,
Blackeyed cowpeas,
Black cowpeas,
Wonderful or Unknown cowpeas,
Whip-poor-will Cowpeas (4 samples),
Brabham cowpeas (2 samples),
Peking cowpeas,
White Crowder Cowpeas,
New Era Cowpeas,
Garbanza or Chick Pea *Cicer arietinum* (2 samples),
Bitter vetch *Vicia ervilia*,
Bitter vetch (Different strain),
Tarheel Black Soy *Glycine hispida*.

The two samples of bitter vetch appeared to be of two different strains, and while the emerging weevils were not numerous in the one sample, they were hard to find in the other. Both samples were well covered with eggs. The Tarheel Black soy beans were also well sprinkled with eggs but I found only three emergence holes, a few young larvæ which had died after entering well into the cotyledons, and one well developed weevil. Continued dissection undoubtedly would have revealed more of the insects.

The following is a list of unprotected seeds upon which I found the eggs of *B. quadrimaculatus* but from which no weevils had emerged.

Red Valentine beans *Phaseolus vulgaris*
Brown Kentucky Wonder Beans
Lady Washington Beans (3 samples)
Prolific Black Wax Beans
Improved Golden Wax Beans
Pinto Beans
Colorado Pinto Beans
Hansen Yellow Beans
Bates Beans
California Pink Beans
Dwarf Spanish Beans
Tepary Beans *P. acutifolius* (3 samples)
Unknown soy beans *Glycine hispida*
Tokio soy beans
Virginia soy beans (2 samples)
O-too-tan soy beans
Moqiu lima *P. lunatus* (2 samples)
Mung Beans *P. aureus*
Rice bean *Phaseolus calcaratus*
Scarlet runner bean *P. multiflorus*
Scarlet vetch *Vicia fulgens* (2 samples)
Vetch *V. monantha* (2 samples)
Wooly podded vetch *V. dasycarpa*
Purple vetch *V. atropurpurae*
Vetch *V. villosa*
Vetch *V. sativa*
Vetch *V. angustifolia*
Corn, Hickory King, *Zea mays*

Corn, Bloody Butcher
Corn, several kinds of Indian corn
Honey Drip sorghum *Andropogon sorgum*
White Kaffir corn
Speltz, *Triticum stacium spelta*
Burbank Superior Wheat *Tr. sat. vulgars*
Kanred Wheat
Turkey Red Wheat
Velvet beans *Stizolobium sp.?* (2 samples)
Chinese White Velvet Beans *Stizolobium* sp.?
Early Bird Velvet Beans *Stizolobium* sp.?
California Red Oats *Avena stavia*
Egyptian cotton
Common Buckwheat *Fagopyrum esculentum* (2 samples)
Japanese Buckwheat *Fagopyrum* sp.?

In every variety of the above seeds except the Egyptian cotton the young larvæ bored through the seed coat before dying. Although the eggs were fairly numerous on the Egyptian cotton seeds, I was unable to find where a single larva had penetrated to the cotyledon. This I concluded was because the eggs were not firmly attached to the seed coat. The fibers to which each egg was attached allowed the chorion to move, thus preventing the larva from obtaining proper support for drilling.

The following is a list of freely exposed seeds upon which I found no eggs of *Bruchus quadrimaculatus*.

Feterita,
Kidney vetch,
Broom Corn,
Alfalfa; different samples of different strains,
White Sweet Clover,
Yellow Sweet Clover,
Kale,
Several kinds of grasses.

The seeds of the feterita and broom corn are small and quite pubescent. It would seem probable that in these cases it was the pubescence and not alone the size of the seeds which prevented oviposition but with the remainder of the seeds in the above list the size appears to be the prohibitive factor.

Observations made in the numerous warehouses of California together with those in other states, indicate that this weevil will oviposit on a great variety of seeds even when its chief hosts are abundant, also that it is unable to develop in any of the following varieties of beans: *P. vulgaris*, *P. lunatus macrocarpus*, *P. lunatus*, *P. acutifolius*, *P multiflorus*, *Stizolobium* sp?.

These observations have been corroborated by extensive experiments in the laboratory. More experiments along this line will be given in connection with the choice of varieties upon which to oviposit.

Host-Selection Shown by Preference for Oviposition of *B. quadrimaculatus.*

Experiment 5.

Ten varieties of common beans were selected and 5 of each variety were placed in Mason jar with a few pairs of *B. quadrimaculatus.* When the weevils were removed it was found that oviposition had occurred as indicated in Table 2, first trial. This was repeated 3 more times using old beans in trials 1, 2, and 4, and freshly harvested beans in trial 3.

Table 2.

Preference for Oviposition of *B. quadrimaculatus* on Ten Varieties of Common Beans.

Variety of Beans	1st Trial, Old Beans	2nd Trial, Old Beans	3rd Trial, Newly Harvested Beans	4th Trial, Old Beans	Total
Bayo	39	36	24	32	131
Cranberry	28	30	21	29	108
Baby Lima	22	22	47	14	105
Kentucky Wonder	19	25	22	28	94
Red Kidney	17	20	44	17	98
Pink	17	16	30	18	81
Refugee Green Pod	15	16	23	28	82
Mexican Red	13	15	29	7	64
Small White	13	13	31	12	69
Teparies	1	7	10	8	26
Total	184	200	281	193	858

Oviposition was permitted to continue in trials 2, 3, and 4 until the number of eggs appeared to approximate the count of trial 1. The object in the later trials was not to obtain equal numbers of eggs but rather to see if the numbers of eggs oviposited on the different varieties would hold approximately the same ratios. The red kidneys and teparies in 1, 2, and 4 had been fumigated with carbon disulphide but no evidence of this was noticable. The Bayos, Cranberries, and Kentucky Wonders used in 3 were not well matured. As this weevil prefers to oviposit on well matured seeds, this may account for the difference in choice between these and other varieties in this trial as indicated by comparing trial 3 with either of the others. While the total number of eggs laid in trial 3 was

greater than in either of the others the numbers laid on the three immature varieties were relatively smaller than in the other trials. In each of the 4 trials there was a very decided preference for certain seeds. As the Bayos were smaller than the Cranberries, Baby Limas, Kentucky Wonders, and Red Kidneys it was evident that the number of eggs on each variety was not in proportion to the amount of surface exposed. There was no emergence from any of these seeds.

Experiment 6.

Thirty-five varieties of peas and beans were selected which differed from each other in color, shape, and size sufficiently to admit their being readily separated. Five perfect seeds of each variety were placed in each of 8 one-quart Mason jars. Into jar No. 1, were placed 2 females and 3 males which had bred in broad windsor beans 2 generations. Nine females and 8 males having bred 3 generations in dwarf sugar peas were placed in jar No. 2. The 41 females and 36 males placed in jar No. 3, had bred 2 generations in prizetaker peas. Into jar No. 4 were placed 52 females and 23 males which had bred 2 generations in blackeyed cowpeas. The 12 females and 10 males, the 11 females and 8 males, 9 females and 7 males, the 7 females and 11 males placed into jars 5, 6, 7, and 8 respectively had bred 8 generations in red ripper cowpeas. Table 3 shows a very nearly uniform preference for oviposition by all these groups of weevils. The jars were laid side by side on a shelf so that the seeds were thoroughly mixed and well exposed. A total of 7692 eggs were laid on the seeds and a few were laid on the jars. Table 3 shows that all of these weevils made practically the same relative choice of seeds for oviposition. In each colum one line (—) alongside of a number indicates that was the number laid on the host from which those were bred. Two lines (=) point out the variety on which they laid the maximum number of eggs.

Figure 3 gives the comparative size of the seeds used in the above experiment. It shows that the weevils were not crowded nearly as much as they frequently are in warehouses. The largest variety of seeds received only about one per cent of the eggs or a number exceeding that on only four of the thirty-five varieties. The seeds are arranged in the ascending order with reference to the number of eggs oviposited on them in the eight jars.

TABLE 3.

Showing the Varieties of Beans upon which *B. quadrimaculatus* Prefers to Oviposit. August, 1922.

Eggs Laid by	2♀3♂	9♀8♂	41♀36♂	52♀23♂	12♀10♂	11♀8♂	9♀7♂	7♀11♂	Total
Variety of Seeds	Bred from Broad Windsor, 2nd Generation	Bred from Dwarf Sugars, 3rd Generation	Bred from Prizetaker Pea, 2nd Generation	Bred from Blackeyed Cowpeas, 2nd Generation	Bred from Red Ripper Cowpeas, 8th Generation	Bred from Red Ripper Cowpeas, 8th Generation	Bred from Red Ripper Cowpeas, 8th Generation	Bred from Red Ripper Cowpeas, 8th Generation	
Garbanza or Chick Pea	0	0	0	3	2	1	0	0	6
Lentils	0	0	8	3*	0	1	0	0	12
Prizetaker Pea	0	0	23—	6	3	0	5	0	37
Dwarf Sugar Pea	0	5—	26	19	12	9	10	2	83
Broad Windsor	0—	0	32	26	12	13	8	2	93
Mammoth Yellow Soy	0	5	32	27	20	10	15	11	120
Phaseolus vulgaris (unknown)	0	5	34	38	21	12	15	8	133
Nicaragua	0	10	38	40	21	11	17	8	145
Black Valentine	0	7	40	35	25	18	21	10	156
Small Windsor	0	0	48	53	15	19	14	9	158
Pink	0	6	42	49	25	17	21	8	168
Burpee's Stringless Greenpod	0	4	36	59	28	19	20	14	180
Baldwin Wonder Wax	0	7	53	47	27	18	18	12	182
Eastern Cornfield	1	6	37	85*	19	14	13	13	188
Pinto	0	9	43	55	22	23	22	18	192
Velvet	0	2	59	61	38	16	19	5	200
Improved Long Yellow, 6 Weeks	1	10	50	54	30	23	21	13	202
Blackeyed Cowpeas	2	5	44	60—	24	27	30	16	208
Mexican Red	0	11	51	49	26	25	26	24	212
Kentucky Wonder Wax	1	3	50	65	34	24	25	14	216
Red Valentine	0	10	54	61	30	26	20	15	216
Holstein Cowpeas	5	16	51	49	32	21	22	26	222
Brown Kentucky Wonders	5	11	51	64	29	24	25	18	227
Lazy Wife	1	8	60	67	37	27	23	19	242
Cranberry	0	12	57	60	27	32	28	17	243
Dutch Caseknife	2	11	60	61	33	31	22	18	247
Red Ripper Cowpea	6	22	59	55	35—	32—	20—	28—	257
Early Mohawk	0	11	70	86	38	24	28	17	274
Italy's Favorite	1	14	71	78	40	26	27	27	284
Bayos	4	18	77	79	43	34	27	25	307
Red Kidneys	2	22	80	87	43	35	30	32	331
Scarlet Summer	3	12	99	100	54	50	56	42	416
Improved Golden Wax	9=	25=	88	99	63	53	40	50=	427
Bush Lima	2	5	131	129	58	57	40	31	453
Ford Hook Lima	8	17	155=	173=	97=	92=	63=	50=	655
Total	58	309	1918	2092	1061	866	791	602	7692

* 10 instead of 5 seeds in this variety.

Emergence From the 7692 Eggs Laid in Experiment 6.

Emergence from the eggs laid by weevils of the second generation from the broad windsor beans and third generation from dwarf sugar peas (table 3, colums 1 and 2) was confined to the cowpea only. Eggs from the second generation from prizetaker pea (column 3) produced adults in the prizetaker pea, dwarf sugar pea, mammoth yellow soy, small winsdor and the cowpeas. Eggs laid by the weevils having been bred in blackeyed cowpeas developed into adult weevils in the garbanza, prizetaker pea, broad and small winsdor, mammoth yellow soy, as well as the cowpeas. Eggs laid in the last 4 jars by weevils having been bred 8 generations in red ripper cowpeas, produced adult weevils in broad, and small winsdor, prizetaker peas, dwarf sugar peas, garbanza and in the cowpeas.

It is interesting to note that from the 35 varieties of seeds of 11 species of plants the weevils were able to develop in only 10 varieties from 7 species and that 6 of these varieties and species were at the bottom of the list in total number of eggs oviposited thereon. Although the seeds were all in good condition the ford hook lima in which the weevil was unable to develop received more than 100 times as many eggs as did the garbanza in which it breeds freely in the absence of other hosts.

Numerous experiments and observations indicate that this weevil breeds freely in the garbanza or chick pea as well as in the prizetaker pea and the dwarf sugar pea when no other host is available. It prefers to oviposit on other hosts such as the bayo and other varieties of *P. vulgaris* when available, although the larvæ are unable to develop in these varieties. In the lentils, broad windsors, and soy beans the weevils breed less freely than in the peas. This is due in the case of the lentils and broad windsors to a high mortality in the young larval and pupal stages as well as to the natural tendency on the part of the adult to avoid ovipositing thereon. The weevils oviposit more freely on the soy beans and there is a lower mortality with the young larvæ but a much higher mortality with second and the older larval stages. In some varieties of soy beans the larval development is so retarded under favorable temperature that at least twice the normal time is required and the emerging weevils are quite small. In these soy beans,

the writer has been unable to get more than 3 generations to develop. This indicates a tendency towards sterility or at least an increasing lack of adaptability such as would be required by the host selection principle.

Other Experiments in 1922 on the Choice of Seeds for Oviposition.

In experiments 7, 8, 9, and 10 seeds were used which were quite similar to some of those used in experiment 6. For convenience in separating them to count the eggs on each variety, only seeds which were easily separated were placed in the same container. In these 4 experiments 23 varieties of seeds were used as shown in tables 4, 5, 6, and 7. These were conducted for the purpose of making further observations as to the seeds chosen for oviposition that deductions could be made as to the underlying reason for such choices being made, and incidentally to determine the varieties in which this species of weevils is able to develop. In all experiments weevils having emerged during the preceding night or later, were used and are designated "newly emerged."

Experiment 7.

Twenty-five beans of each of the following varieties were placed in a pint Mason jar with 4 pairs of newly emerged weevils: Osceola velvet, biloxi soy, Mexican tree bean, mammoth yellow soy, O-too-tan soy. They are here listed according to size in descending order. In this group the number of eggs laid on each variety was more nearly proportional to the size of the seeds than in any other group. A total of 322 eggs were laid with a very marked preference being shown. Weevils emerged from only the three varieties of soy beans.

Table 4.

Showing Preference of Variety of Beans for Oviposition by 4 Pairs of *Bruchus quadrimaculatus*. August, 1922.

	Number of Eggs on Each Bean																													
O-too-tan Soy	0	2	0	1	0	1	1	3	1	0	0	0	0	1	1	1	0	0	0	0	2	1	2	0	1=	18
Biloxi Soy	2	2	1	1	2	2	2	2	1	2	3	3	1	1	1	2	2	1	2	2	1	4	0	2	2	44
Mammoth Yellow Soy	2	4	2	2	2	2	1	3	2	4	2	2	2	3	3	2	2	2	2	3	4	3	1	3	2	60
Mexican Tree Bean	2	4	4	4	3	5	3	2	3	2	3	2	7	1	3	3	2	1	2	2	3	4	3	3	4	75
Osceola Velvet	6	6	7	6	4	5	9	2	3	7	4	5	2	3	6	6	7	5	4	5	4	4	5	4	6	125
Total																										322

Experiment 8.

In this experiment 25 seeds of each of 6 varieties as shown in table 5 were placed with 6 pairs of newly emerged weevils. In this, as in all the other experiments the seeds were well mixed before the jars were laid on the shelf. The weevils were allowed to remain in the jar undisturbed until they were dead. The seeds were then separated and the eggs counted. Weevils emerged from only the American wonder pea and the broad windsor.

TABLE 5.

Showing Preference of Variety of Beans for Oviposition by 6 Pairs of *B. quadrimaculatus*, August, 1922.

	Number of Eggs on Each Bean																													
American Wonder Pea...	2	0	0	0	0	0	1	0	0	0	0	1	0	2	1	1	1	1	1	0	0	0	0	0	0	=	11
Broad Windsor.....	2	0	0	0	0	1	3	5	1	2	0	1	3	3	1	0	0	2	0	1	0	1	0	0	0		26
Navy.....	1	2	2	2	2	2	4	2	3	2	1	1	3	1	2	2	2	1	2	1	2	2	1	2	3		47
Full Measure Bean.....	2	6	3	3	6	3	3	4	1	2	1	3	3	5	6	3	3	1	4	4	1	7	3	4	4		85
Pink.....	2	3	2	4	5	4	5	6	4	4	5	4	4	3	3	2	4	2	4	3	2	3	4	5	4		91
King of Garden Lima....19	10	13	4	13	15	9	8	11	15	9	8	9	9	11	8	8	8	13	18	6	10	15	13	17		279
Total.....																														539

Experiments 9 and 10 were similar to the preceding experiments except that different varieties of seeds were used as shown in Tables 6 and 7. No weevils emerged from any of these seeds.

TABLE 6.

Showing Oviposition of 7 Pairs of *B. quadrimaculatus*, August, 1922.

	Number of Eggs on Each Bean																													
Tepary.....	1	1	1	1	2	1	1	1	0	1	1	2	1	0	0	0	0	0	1	3	1	1	0	1	3	=	24
Creaseback.....	1	3	2	3	2	2	2	2	4	1	1	1	1	1	2	2	1	3	2	5	1	2	2	2	3		51
Reuters Longfellow.....	4	3	3	3	3	2	4	3	5	3	5	3	2	6	3	3	2	4	3	4	3	6	5	4	3		89
Wonderful Kidney Wax..	4	6	5	4	4	6	3	3	3	1	5	5	2	3	7	5	3	1	6	6	3	6	5	3	9		108
Cranberry.....	6	5	6	3	4	4	5	4	3	6	4	4	5	7	6	4	7	5	6	7	4	3	6	4	3		121
Giant Pod Lima.....	6	9	12	10	10	5	3	7	5	3	10	4	11	5	9	9	5	5	3	7	8	10	7	6	6		175
Total.....																														568

TABLE 7.

Showing Oviposition of 6 Pairs of *B. quadrimaculatus*, August, 1922.

	Number of Eggs on Each Bean																													
Extra Early Refugee.....	1	1	1	3	2	1	4	2	1	4	3	2	2	1	1	4	2	2	0	1	1	2	1	4	4	=	50
Refugee Wax.....	3	2	1	3	1	2	2	3	1	2	4	2	2	2	1	2	1	1	2	2	2	3	3	2	2		51
Prolific Black Wax.....	1	1	3	3	6	4	2	4	2	3	2	0	3	5	2	3	2	3	4	2	2	2	2	3	1		65
Canadian Wonder.....	4	5	5	3	6	4	5	4	5	3	4	7	3	4	6	3	5	4	8	4	5	6	4	3	5		115
Ventura Wonder Wax....	5	4	5	3	3	5	5	4	5	5	3	4	4	7	4	5	4	6	8	5	4	4	6	5	5		118
Field Lima.....	8	9	8	7	6	2	8	7	7	6	3	6	3	5	5	4	7	5	7	6	8	8	5	6	3		149
Total.....																														548

Experiments in 1923.

Early in 1923 the writer received a number of varieties of seeds from the U. S. D. A. Bureau of Plant Industry. Because of the similarity of certain varieties of seeds it was necessary, while trying to determine the choice for oviposition and the hosts in which this weevil can breed, to divide these seeds into two groups as shown in Table 8 and 10. The weevils used throughout these experiments emerged from red ripper cowpeas after being bred there-in for 13 generations.

Experiment 11.

On July 5th, 5 pairs of newly emerged *Bruchus quadrimaculatus* were placed in each of 10 containers (pint Mason jar) with 5 seeds of each of the 23 varieties listed in table 8. These were placed in favorable location for observation. On July 13 the weevils were removed, the seeds were separated so that the eggs could be tabulated.

Table 8.
Choice of Seeds for Oviposition, July, 1923.

Kind of Seed	Number of Containers										
	1	2	3	4	5	6	7	8	9	10	Total
Vicia ervila	1	5	4	0	1	1	2	0	3	2	19
Vicia villosa	4	6	1	1	0	4	4	1	5	3	29
Lathyrus tingitanus	8	7	12	0	1	9	4	0	5	9	55
Mung bean	5	8	3	8	6	8	8	2	6	10	64
Urd bean	9	8	8	5	3	7	11	2	4	10	67
Vicia monantha	10	11	9	3	5	6	9	1	5	11	70
Lathyrus sativus	14	11	5	1	4	10	10	9	8	8	80
Rice bean	12	11	4	9	11	11	9	16	8	11	102
Cajanus indicus	14	11	13	3	8	11	14	15	12	19	120
Virginia soy	19	19	13	14	16	11	16	10	10	19	147
Hyacinth bean 47568	27	16	11	9	15	17	15	18	13	18	159
Hyacinth bean 27532	32	15	17	7	14	15	21	15	19	20	175
Wilson five soy	15	21	16	15	20	18	15	16	13	27	176
Buff catjang	22	16	17	23	15	24	18	22	18	19	194
Vicia faba	16	24	21	9	17	24	20	21	21	31	204
East cook soy	24	24	20	13	15	19	26	20	16	31	208
Adzuki-red	22	31	27	27	17	19	22	14	10	25	214
Brabham cowpea	28	25	29	20	25	22	16	20	16	22	223
Adzuki-speckled	30	31	29	30	30	26	23	19	23	23	254
Hahto soy	26	21	30	8	23	25	25	25	26	46	255
Conch	31	23	24	25	25	24	24	27	25	33	261
New Era Cowpea	31	24	31	27	25	23	27	29	23	28	268
Large blackeyed cowpeas	32	36	23	35	29	21	30	18	22	35	281
Total	432	404	367	292	315	355	369	320	311	460	3625

Although the number of eggs in the various containers varied from 292 to 460 the number of eggs oviposited on the different varieties of seeds holds quite a regular relationship in each container. More than 14 times as many eggs were laid on the large blackeyed cowpea as on black bitter vetch *Vicia ervilia*. A total of 3625 eggs were recorded. The emergence from these eggs is recorded in table 9, which shows that weevils emerged from all but 5 of the 23 varieties or in 11 different species of hosts.

TABLE 9.

Emergence Record of *B. quadrimaculatus* from 23 Varieties of Seeds, Eggs Laid July, 1923.

Kind of Seed	Number of Eggs	♂	♀	Number Emerged	Percent Emerged	Date of First Emergence	Date of Last Emergence	Second Generation
Vicia ervilia	19	0	0	0	.....	.....	.....	.....
Vicia villosa	29	0	0	0	.....	.....	.....	.....
Lathyrus tingitanus	55	0	0	0	.....	.....	.....	.....
Mung bean	64	27	20	47	73.4	8-8	8-21	9-20—9-29 (8♂ 10♀)
Urd bean	67	0	3	3	4 4	9-21	10-13	.....
Vicia monantha	70	0	0	0	.....	.....	.....	.....
Lathyrus sativus	80	18	22	40	50.	8-18	8-31	10-15—10-31 (10♂ 11♀)
Rice bean	102	0	0	0	.....	.....	.....	.....
Cajanus indicus	120	42	23	65	54 1	8-15	8-30	9-20—10-27 (19♂ 4♀)
Virginia soy	147	1	0	1	.6	10-20	.....	.....
Hyacinth bean 47568	159	25	26	51	32.	8-23	9-29	.....
Hyacinth bean 27532	175	26	18	44	25.1	8-20	9-14	11-6—1♀
Wilson five soy	176	5	5	10	5.6	9-7	10-5	.....
Buff catjang	194	64	52	116	59.7	8-6	9-29	11-6—1♂ 1♀
Vicia faba	204	2	3	5	2.4	8-23	9-11	.....
East cook soy	208	10	14	24	11.5	9-3	10-1	.....
Adzuki-red	214	71	54	125	58.8	8-13	9-8	9-29—11-6 (23♂ 16♀)
Brabham cowpea	223	69	57	126	56.5	8-10	9-29	10-31, 1♂; 11-6, 1♂ 1♀
Adzuki-speckled	254	81	52	133	52.3	8-11	10-24	.....
Hahto soy	255	17	21	38	14.9	9-3	10-1	10-27, 1♂
Conch	261	94	68	162	62.	8-9	10-10	.....
New Er. cowpea	268	51	50	101	37 7	8-13	8-30	10-3—10-17, 5♂ 2♀
Large blackeyed cowpea	281	113	99	212	75.4	8-7	10-3	10-27—11-6, 8♂ 3♀
Total	3265	716	587	1303	36.2	8-6	10-24	

The difference in the ability of this weevil to develop in the various varieties is well marked, the emergence varing from 0 to more than 75 per cent. This record corroborates observations the writer has frequently made that when breeding

in an unfavorable host there is usually a preponderance of males among those that are able to develop. This is sometimes noticeable when breeding in the more favorable hosts. As is indicated in the above table a second generation developed in several varieties as a result of eggs laid before the recorded weevils were removed.

Experiment 12.

In this experiment 2 pairs of newly emerged weevils were placed in each of 10 Mason jars with 5 seeds of each of the 10 varieties listed in Table 10. Here also the choice is very

TABLE 10.

Choice of Seeds for Oviposition, July, 1923.

Name of Seed	Container Number										
	1	2	3	4	5	6	7	8	9	10	Total
Ervum lens	3	5	7	2	11	0	5	4	6	3	46
Vicia atropurpurea	4	6	5	6	7	5	8	2	7	4	54
Vicia dasycarpa	6	15	6	12	15	11	16	5	8	7	101
Lathyrus clymenum	9	9	13	12	12	11	12	4	13	14	109
Peking soy	9	21	13	17	19	10	14	7	12	12	134
Adzuki-buff	12	17	15	18	24	17	20	15	13	16	167
Manchu soy	21	18	17	24	29	19	24	1	17	20	190
Early red cowpea	13	23	19	23	19	36	19	23	17	17	209
Moneta cowpea	15	27	22	25	33	34	30	11	19	19	235
Groit cowpea	25	28	22	28	28	31	21	15	21	21	240
Total	117	169	139	167	197	174	169	87	133	133	1485

pronounced. Of the 1485 eggs more than 5 times as many were laid on the groit cowpea as on the lentils, *Ervum lens*. The emergence from these eggs is recorded in Table 11.

Here as in table 9 there is a great range in the ability of the weevils to breed in the different varieties. Here also ther were more males than females. Tables 9 and 11 indicate that the mung bean, *Cajanus indieus*, Buff catjang, and the Adzuki beans are as favorable for development as the cowpeas and only a little less favorable for oviposition.

TABLE 11.

Emergence Record of *B. quadrimaculatus* from Various Seeds.
Eggs Laid July, 1923.

Kind of Seed	Number of Eggs	♂	♀	Number Emerged	Percent Emerged	Date of First Emergence	Date of Last Emergence	Second Generation
Ervum lens	46	8	6	14	30.4	9-5	9-27	
Vicia atropurpurea	54	0	0	0				
Vicia dasycarpa	101	0	0	0				
Lathyrus clymenum	109	0	2	2	1.8	9-4	9-4	
Peking soy	134	0	0	0				
Adzuki-buff	167	60	51	111	66.4	8-14	10-29	
Manchu soy	190	3	4	7	3.6	9-11	9-22	
Early Red cowpea	209	54	49	103	49.2	8-10	9-4	9-20—10-15, 58♂ 43♀
Moneta cowpea	235	82	53	135	53.1	8-10	9-13	9-20—10-15, 53♂ 38♀
Groit cowpea	240	24	23	47	19.5	9-11	10-23	
Total	1485	231	188	419	28.2	8-10	10-29	

Experiment 13.

On July 19, 5 pairs of newly emerged weevils were placed in each of 10 containers along with 5 seeds of each of the 29 varieties recorded in table 12, 3602 eggs were recorded, some being laid on all but two varieties of seeds. Previous experiments have shown that these two, the chick pea, and the little marvel pea, are favorable for the development of all stages of the weevil. The choice for oviposition on the 50 seeds of each variety ranged from nothing on the two varieties and 3 on the broad windsor to 308 on the bush lima. This was more than 100 times as many eggs on a variety which is favorable for oviposition but in which the weevil cannot develop, as were laid on a variety of equal or greater size which was unfavorable for oviposition but in which the weevil can develop.

Table 13 shows the emergence from the eggs recorded in Table 12. It corroborates the findings in the preceding experiments with no emergence from many varieties and with an emergence of less than 4 percent in some of the soy beans to 82.5 percent in the red ripper cowpeas. In this experiment as in all those preceding it, the eggs hatched normally on all

varieties of seeds. Even in the most favorable varieties there is a higher mortality amongst the larvæ of the first stage than of any later stage. In fact in these varieties under normal conditions there is practically no mortality after the first larval stage. In the soy beans it appears that the mortality is greatest

TABLE 12.

Choice of Seeds for Oviposition, July, 1923.

Kind of Seed	Number of Containers										
	1	2	3	4	5	6	7	8	9	10	Total
Little Marvel Pea	0	0	0	0	0	0	0	0	0	0	0
Chick pea	0	0	0	0	0	0	0	0	0	0	0
Broad Windsor	0	0	0	0	2	0	1	0	0	0	3
P. vulgaris, Vari. unknown	3	3	1	2	2	4	0	6	6	4	31
O-too-tan soy bean	5	5	1	3	3	3	4	2	5	2	33
Castor bean	0	0	3	5	3	1	10	8	6	3	39
Pinto bean	2	7	1	5	8	3	9	5	10	1	51
Navy bean	11	7	1	7	8	2	12	5	10	4	67
Kentucky Wonder	7	5	2	7	8	3	11	7	14	7	71
Kentucky Wonder (brown)	7	6	5	7	17	6	7	11	15	9	90
Lazy Wife	5	11	3	12	11	4	14	11	9	11	91
Biloxi soy	8	11	4	10	14	10	7	12	10	9	95
Mammoth yellow soy	9	9	8	10	19	6	12	12	11	6	102
Prolific black wax	11	8	5	5	13	7	19	13	13	8	102
Velvet bean	6	7	5	9	15	9	13	12	20	12	108
Extra early refugee	9	11	6	6	13	5	18	15	14	12	109
Improved six weeks	13	11	4	4	16	3	20	12	13	19	115
Early Mohawk	14	12	4	6	11	10	18	14	17	15	121
Canadian Wonder	19	13	3	12	28	4	19	18	19	17	152
Scarlet runner	5	22	1	11	35	20	19	20	15	18	166
Red Kidney	16	7	13	17	29	12	23	19	24	19	179
Blackeye	24	19	34	26	22	23	6	8	16	8	186
Improved golden wax	21	16	17	15	20	18	24	27	23	15	196
Red ripper	29	9	30	23	12	29	9	18	28	14	201
Ventura Wonder Wax	30	20	14	19	33	20	26	18	24	24	228
Speckled cranberry	29	14	12	19	37	25	23	22	26	27	234
Holstein	37	26	26	26	21	41	14	19	33	13	256
Fordhook lima	25	19	17	21	33	15	28	35	29	36	258
Burpee's Imp. Bush Lima	27	19	28	36	38	17	39	42	29	33	308
Total	372	297	258	323	471	300	405	391	439	346	3602

a few days after the larvæ have entered the seed or in the second larval stage, but there is a high mortality and a retarded development in all the larval stages. In the common beans and some other varieties of seeds the larvæ appear to die shortly after eating the first bit of the cotyledon.

TABLE 13.

Emergence Record of *B. quadrimaculatus* on Various Seeds.
Eggs Laid July, 1923.

Kind of Seed	Number of Eggs	♂	♀	Number Emerged	Percent Emerged	Date of First Emergence	Date of Last Emergence	Second Generation
Little Marvel Pea...	0	0	0	.....	.....	.....	.....	.....
Chick Pea.....	0	0	0	.....	.....	.....	.....	.....
Broad Windsor.....	3	0	0	.....	.....	.....	.....	.....
P. vulgaris, vari. unknown.....	31	0	0	.....	.....	.....	.....	.....
O-too-tan soy bean..	33	3	3	6	18.1	9–15	10–24	.....
Castor bean.....	39	0	0	.....	.....	.....	.....	.....
Pinto bean.....	51	0	0	.....	.....	.....	.....	.....
Navy bean.....	67	0	0	.....	.....	.....	.....	.....
Kentucky Wonder..	71	0	0	.....	.....	.....	.....	.....
Brown Kentucky Wonder.....	90	0	0	.....	.....	.....	.....	.....
Lazy Wife.....	91	0	0	.....	.....	.....	.....	.....
Biloxi soy.....	95	4	1	5	5.2	9–27	10–2	.....
Mammoth Yellow soy.....	102	7	0	7	6 7	8–29	10–1	.....
Prolific Black Wax..	102	0	0	.....	.....	.....	.....	.....
Velvet bean.....	108	0	0	.....	.....	.....	.....	.....
Extra Early Refugee	109	0	0	.....	.....	.....	.....	.....
Improved six weeks	115	0	0	.....	.....	.....	.....	.....
Early Mohawk.....	121	0	0	.....	¼	.....	.....	.....
Canadian Wonder...	152	0	0	.....	.....	.....	.....	.....
Scarlet Runner.....	166	0	0	.....	.....	.....	.....	.....
Red Kidney.....	179	0	0	.....	.....	.....	.....	.....
Blackeyed cowpea..	186	92	54	146	78.5	8–23	9–6	10–3—10–29 (6♂ 8♀)
Improved Golden Wax.....	196	0	0	.....	.....	.....	.....	.....
Red Ripper Cowpea	201	72	94	166	82.5	8–23	9–5	10–3—10–15 (9♂ 11♀)
Ventura Wonder Wax	228	0	0	.....	.....	.....	.....	.....
Speckled cranberry.	234	0	0	.....	.....	.....	.....	.....
Holstein Cowpea....	256	88	70	158	61.7	8–23	9–8	10–3—10–20 (3♂ 1♀)
Fordhook Lima.....	258	0	0	.....	.....	.....	.....	.....
Burpee's Imp. Bush Lima.....	308	0	0	.....	.....	.....	.....	.....
Total.....	3602	266	222	488	13.5	10–24	.....	.....

The following is a list of seeds from which the writer has bred *Bruchus quadrimaculatus* experimentally:

Early rams horn blackeyed cowpeas, *Vigna sinensis*,
Mammoth blackeyed cowpea,
Blackeyed cowpea of two or three other strains,
Groit Cowpea,
Black,
Wonder or Unknown,
Early Red,
Moneta,
Whip-poor-will,
Brabham,
Peking,
White crowder,
New Era,
Holstein,
Red ripper,
Iron,
Clay,
Wilson,
Blackeyed brown,
Yard long or asparagus bean *Dolichos sesquipedalis*,
Cajanus indicus,
Lentils *Ervum lens*,
Garbanzo or chick pea *Cicer arietinum*,
Tarheel black soy *Glycine hispida*,
Biloxi soy,
O-too-tan soy,
Mammoth yellow soy,
Virginia soy,
Wilson five soy,
Easy Cook soy,
Hahto soy,
Machu soy,
Prizetaker pea *Pisum sativum*,
American Wonder,
Dwarf Telephone,
Admiral,
Little Marvel,
Hulbert field,
Warshaver field,
Canada field,
Colorado stock,
Chickling vetch, *Lathyrus sativus*,
Lathyrus *Lathyrus clymenum*,
Bitter vetch *Vicia ervilia*,
Bitter vetch, Different strain,
Broad windsor or horse bean *Vicia faba*,
Small windsor *Vicia faba*,
Buff catjang,
Adzuki-red *Phaseolus angularis*,
Adzuki-speckled *Phaseolus angularis*,
Adzuki-buff *Phaseolus angularis*,
Mung bean *P. aureus*,
Urd bean *P. mungo*,
Hyacinth bean (47568). (No. given by Bureau of Plant Industry),
Hyacinth bean (27532). (No. given by Bureau of Plant Industry),
Conch bean.

Most of the varieties here recorded have been used repeatedly in unlisted experiments to check on the ability of this weevil to breed therein. In some instances, notably with soy beans and broad and small windsor beans it has been found that the weevil failed to develop in certain lots while it developed in others. This seems to indicate that under certain conditions seeds of a given variety may be more toxic to young larvæ than under other conditions. It is very probable that *B. quadrimaculatus* may be found to be able to breed in many more varieties of seeds which have been unavailable for these experiments. Under some conditions it may even breed in some in which the writer has been unable to get it to develop.

The fact that this weevil oviposits freely on many varieties of cc mmon garden beans and is therefore found quite frequently amongst such beans probably accounts for the erroneous statements so frequently made that it works in common beans. The results of experiments with 50 or more varieties of *P.*

vulgaris which includes the common garden beans, seems to indicate that they are quite unsuitable for the larval development of this weevil.

The following is a list of seeds from which the writer has not been able to breed it, although eggs have been deposited more or less freely on each variety:

Red Valentine Bean, *Phaseolus vulgaris*,
Brown Kentucky Wonder,
Lady Washington,
Prolific Black Wax,
Improved Golden Wax,
Pinto,
Colorado Pinto,
Hanson Yellow,
Bates,
California Pink,
Dwarf Spanish,
Nicaragua,
Black Valentine,
Burpee's Stringless Greenpod,
Baldwin's Wonder Wax,
Eastern Cornfield,
Long Yellow Six Weeks,
Mexican Red,
Kentucky Wonder Wax,
Superior Kentucky Wonder,
Brown Kentucky Wonder,
White Kentucky Wonder,
Lazy Wife,
Cranberry,
Dutch Caseknife,
Early Mohawk,
Improved Early Mohawk,
Italy's Favorite,
Bayo,
Red Kidney,
Black Wax,
Navy,
Navy Bluepod,
Large White,
Small White,
Creaseback,
Reuter's Longfellow,
Wonderful Kidney Wax,
Refugee Greenpod,
Ventura Wonder Wax,
Full Measure (and 9 other varieties of *Phaseolus vulgaris*, whose common names are unknown to the writer)
Rice Bean *Phaseolus calcaratus*,
Tepary *P. acutifolius*,
Scarlet Runner *P. multiflorus*,
Large White Lima *P. lunatus macrocarpus*,
Giant Pod Lima,
Ford Hook Lima,
Field Lima,
King of Garden Lima,
Henderson Bush Lima *P. lunatus*,
Moki Lima,
Velvet Bean *Stizolobium* sp?,
Chinese White Velvet Bean,
Early Bird Velvet Bean,
Mexican Tree Bean,
Castor Bean *Ricinus communis*,
Woolly Podded Vetch *Vicia dasycarpa*,
Vetch *V. monantha*,
Purple Vetch *V. atropurpurea*,
Hairy Vetch *V. villosa*,
Oregon Vetch *V. sativa*,
Narrow-leafed Vetch *V. angustifolia*,
Vetch *P. pamonica*,
Tanager pea *Lathyrus tingitanus*,
Hickory King Corn *Zea maise*,
Bloody Butcher Corn,
Several kinds of Indian Corn,
White Kaffir Corn,
Honey Drip Sorghum,
Speltz,
Burbank Superior Wheat,
Kanred Wheat,
Turkey Red Wheat,
California Red Oats,
Common Buckwheat,
Japanese Buckwheat,
Egyptian Cotton.

In every variety of the above seeds, except the Egyptian Cotton, the young larvæ have bored through the seed coat, but in no case did the tiny weevil develop to any appreciable extent before dying. Many of the larvæ died before their bodies were entirely out of the egg shells, but others were able to gnaw minute holes through the testa of the seeds, and still others penetrated a short distance into the cotyledons.

It has not been determined that this weevil would be able to pass through its later larval stages in any of these hosts which prove fatal to all first stage larvæ. After repeated failure in getting the larvæ to live when transferred from blackeyed cowpeas to pink beans the writer tried transferring larvæ from blackeyed cowpeas to other blackeyed cowpeas. In order to make such a transfer it is necessary to dissect a larva out of one seed and insert it into another. Because of the body structure and the feeding habits of the larvæ, it was difficult to make a cavity in the new seed which was suitable.

When the larva hatches it depends upon the egg shell to support its prothoracic plates, which Kannan (33) points out, are used as levers for bracing and shifting the body as the latter by means of a peristaltic movement, enables the chisel like mandibles to drill or chissel off tiny bits of the host. The older larvæ depend upon the walls of the cavities to support their bodies as the choria supported the young larvæ while they were effecting entrance. From the time the insect enters the seed the cavity is enlarged proportionally to the growth of the body. Frequently a larva will break the wall of its cavity and fall or wiggle into the central cavity so generally found in the blackeyed cowpea and there will die or gouge out some food on each side and pupate within this central cavity. Weevils that pupate in this cavity usually are undersized because of lack of food and the adult dies without making an exit. When a large larva enters the central cavity of the seed it has a better opportunity to brace its body and make a cavity to fit its body thus being enabled to make its way near the outer surface of the seed before pupating. Young larvæ frequently enter the chambers made by larger larvæ and there die of starvation.

The writer when transferring larvæ from one bean to another was unable to overcome the difficulty of getting a properly fitted cavity. Only a few weevils thus transferred from one blackeyed cowpea to another were successful in reaching maturity. These were undersized. None developed when transferred to garden beans.

Some larvæ transferred into and buried with finely powdered blackeyed cowpeas were retarded in their development but finally emerged as adults but the majority failed to emerge. None emerged from flour made from garden beans.

Retarded development of the larvæ which were buried in flour made from the cowpeas seems to indicate the inability of the larvæ to obtain sufficient food for proper development and not that the food which was ingested was unsuitable for growth. Total failure to develop when thus buried in bean flour seems to indicate that this material was unsuitable for food. In this connection Bridwell (32) says: "It is not improbable that the inability of bruchids to breed in legumes otherwise similar in composition to their host seeds may be due to the diversity of their proteids."

Retarded development of the larval stages within soy beans appears to be due to one of the two causes; first, the inability of the larvæ to obtain sufficient food and second the lack of some necessary elements. If the latter were the chief cause it would seem that a very much greater percentage would die in the first stage; that only a very few would reach the second stage. However, it appears that more larvæ die in the second stage and in each succeeding stage than die in the first larval stage. The writer interprets this to indicate the inability of the second stage larvæ to obtain sufficient food. The first stage larvæ are able to get sufficient food because their prothoracic plates are better developed and used more in this stage than in any other. In this stage the use of these plates enables the larvæ to hold the body firmly in the desired position while food is being obtained. In the later stages the larvæ depend less on these plates and more on the rest of the body. The body appears to be unable to hold firmly in position within the cavity of the oily soy bean. The body with the less functional prothoracic plates skid so to speak, causing the larvæ to die of slow starvation or to develop slowly. The emerging adults are reduced in vigor and vitality and produce only a few eggs so that a heavy infestation dies out in a few generations.

So far the writer has not been able to prove definitely that the retarded development is not due to a lack of some necessary element. A quite similar retarding of development can be noticed within cowpeas when there is an insufficient air supply as is the case when the cowpeas are kept inside of vials sealed with paraffined corks. If the enclosed seeds are only lightly infested the development of the later larval stages is retarded. If the seeds are heavily infested the larval development is greatly retarded or even killed. When a lack of air causes a

slow larval growth it causes a high mortality of the pupæ. This high death rate among the pupæ seems to be due to the complete vitiation of the air. Such a condition does not exist within the soy beans. There is no evidence to indicate that the weevils within the soy beans in normal or unsealed containers do not obtain sufficient air. The mortality amongst the pupæ is not great enough to indicate an accumulative effect as is indicated in the cowpeas.

The foregoing experiments indicate that this weevil oviposits freely on a great many varieties but it shows a consistant choice of certain varieties in nature or in experiments.

It oviposits freely on some varieties even in which there is a total mortality of the young larval stage but it shows a marked hesitancy in ovipositing on other varieties in which the young larvæ cannot survive. Again oviposition occurs freely on some seeds in which the mortality of all larval stages is high but from which some individuals emerge as adults. While it oviposits freely on certain varieties which are favorable for all stages of development it almost refuses to oviposit on other varieties which seem to be equally favorable for larval development. For example there seems to be no higher larval mortality in the chick pea than in any of the cowpeas but the weevil seldom oviposits on the former when the latter are equally available.

This indicates that there are certain seeds which are favored for oviposition and certain ones which are avoided. The fact that the weevils consistantly avoid ovipositing on certain varieties of seeds even after having bred therein for several generations indicates that there is no inherited predilection for that host. Continued breeding in a host does not appear to intensify the preference for that host.

There seems to be a predilection for seeds having smooth well filled coats. This has been borne out by all the foregoing experiments. It is further borne out by the fact that the weevil oviposits quite freely on painted lead pencils, varnished handles, door frames which have been stained and varnished, but refuses to oviposit on rough or unpolished wood.

That the sense of touch is very highly developed in the adult weevils is indicated by the fact that they never oviposit on split beans or broken seeds of any variety where sound seeds can be found. Cowpeas or other seeds having seed

coats which have become loosened are always passed over if other seeds are available. Some seeds have wrinkled coats while others have smooth coverings. The weevil's sense of touch seems to be able to differentiate between these two types of coverings. This is illustrated better with the Holstein cowpeas than with any other that I have noticed.

This cowpea seems to be a direct cross between a black smooth skinned cowpea and a white rough skinned variety. It is variable in color markings as well as in the texture of the seed coat, there being all gradations from white with a few black spots to black with a small white area, and from smooth to quite wrinkly. Some of these seeds have coats which are partly smooth and partly rough. On seeds of this kind the choice of the weevil is frequently quite noticeable, the smooth area having been oviposited on while the other portion of the seed is free from oviposition.

That some factor besides the smoothness of the seed coat may have a bearing on the choice of seed for oviposition is evidenced by the way the tepary bean is avoided. The surface of this bean appears to be as favorable as that of several other varieties which are selected while it is not. There is a difference between the seed coat of this bean and any other with which the writer is familiar in that as soon as it is moistened it begins to wrinkle. This difference is not apparent until the seed coat is moistened.

If the sense of touch is responsible for the selection of seeds for oviposition as it appears to be, the next question is, where this highly developed sense organ is located. Is it the antennae or the mouthparts or the feet and legs, or is it the ovipositor? The writer after studing the oviposition of numerous weevils is inclined to think that all of these parts of the weevil function in this respect. The weevil will walk over some seeds without showing any reaction while it will carefully feel others with its antennae, its mouthparts and finally extrude its ovipositor several times before selecting a location for the egg. On other seeds it will oviposit without giving any apparent concern to the location. In some cases the feet and legs appear to determine the desirability or the undesirability of the seeds.

The egg is surrounded by a gelatinous liquid which soon hardens and cements it to the host. The weevil apparently never turns around to examine the spread of this cement around the egg.

Conclusions.

Bruchus quadrimaculatus Fab. which normally breeds in cowpeas can breed in many varieties of leguminous seeds.

Oviposition takes place more freely on well matured seeds of any variety than on unmatured or broken seeds of the same variety.

The adults show a marked predilection for well filled seeds having a smooth polished seed coat.

With reference to the choice for oviposition, seeds may be divided into the following groups:

1. Seeds which are favorable for oviposition:
   (a) Seeds which are favorable for all stages of development, cowpeas furnishing examples.
   (b) Seeds in which weevils cannot develop, some of the limas and common beans *P. vulgaris* being examples.
2. Seeds which are less favorable for oviposition:
   (a) Seeds which are favorable for all stages of development, some varieties of cowpeas and Adzuki beans being examples.
   (b) Seeds which are unfavorable for development in some stages, but in which some weevils are able to develop, soy beans being examples.
   (c) Seeds in which the weevils do not develop, many common beans *P. vulgaris* are examples.
3. Seeds which are unfavorable for oviposition:
   (a) Seeds which are favorable for all stages of development, Chick peas are an example.
   (b) Seeds which are unfavorable for development in some stages, broad windsor for example.
   (c) Seeds in which the weevils can not develop, the tepary is an example.

The adults show no marked predilection for the host in which they have bred.

Continued breeding in a host does not appear to intensify the preference for that host.

The adult oviposits as freely on hosts which are unfavorable for larval development as on hosts which are favorable for such development.

Any inherited tendency toward the formation of host strains or phytophagic species would have to be exhibited by the adult only, because the eggs are glued to the host and the young have no means of gaining access to a host if the egg is not firmly attached. Any host which is unfavorable to the

young larvæ precludes the possibility of its being favorable to later stages.

The Host-Selection Principle as outlined by Hopkins does not appear to hold with this insect.

The four-spotted bean weevil *Bruchus quadrimaculatus*, does not appear to be able to breed in any variety of common garden beans *Phaseolus vulgaris*.

Because of the inability of *Bruchus quadrimaculatus* to breed in common beans, its misleading common name should be changed to "four-spotted cowpea weevil."*

LITERATURE CITED.

1. **1916. Hopkins, A. D.** U. S. Dept. Agr. Program of Work, 1917, p. 353, 1916.
2. **1923. Craighead, F. C.** Canadian Entomologist, V. 55, No. 4, p. 76-79, April, 1923.
3. **1864. Walsh, D. B.** Proc. Ent. Soc. Phila., Vol. 3, page 403–430, 1864.
4. **1865. Walsh, D. B.** Proc. Ent. Soc. Phila., Vol. 4, pages 194–216, 1865.
5. **1922. Craighead, F. C.** Journ. Arg. Res., Vol. 22, No. 4, pages 189–220, October 2, 1922.
6. **1923. Belyea, Harold Cahill.** Jour. Forestry, Vol. XXI, No. 4, p. 384.
7. **1905. Pictet, Arnold.** Mem. Soc. Phy. et. Hist. Nat., Geneve, Vol. 35, fasc. 1, pages 45–127, pl. 2–5. 1905.
8. **1907. Schroder, Chr.** 1905. In Ztschr, Wiss, Insektenbiol., Bd. 3, p. 162–164, 1907.
9. **1903. Schroder, Chr.** Verhandl. Deut. Vool. Gosell., Jahresversamml. 13, p. 158–166. 1903.
10. **1908. Marchal, Paul.** Compt. Red. Soc. Biol. (Paris), t. 65, p. 2–5, 1908.
11. **1920. Brues, C. T.** Amer. Nat., Vol. 54, No. 633, p. 312–332. 1920.
12. **1920. Roubaud, E.** Ann. d. l'Inst. Past. XXXIV, 1920, p. 181.
13. **1921.** Bul do la Soc. Path. Exot. XIV, 1921, p. 557.
14. **1923. Howard, L. O.** Proc. 10th An. Meeting N. J. Mosquito Association, Feb., 1923, pages 10–25.
15. **1921. Wesenberg-Lund, C.** Mem. Acad. R. Sciences et Lettres Danemark, (Sect. Des Sci.), 1920, 1921, 8th Ser., Vol. 7, No. 1, p. 1–210.
16. **1924. Barbar, M. A.,** and **Hayne, T. B.** Public Health Reports, Vol. 39, No. 4, page 144.
17. **1918. Capus, Joseph,** and **Marchal, Paul.** Compt. Rend. Acad. Agri. France, t. 4, No. 25, pages 712–716. 1918.
18. **1920. Nilsson-Ehle, H.** "Uber Resistens gegon Heterodera Schachtii bei gewissen Gersten-sorten, ihre Vererbungsweise und Bedeutung fur die Praxis." (On the resistance of certain barley varieties to Heterodera Schachtii, its inheritance and practical significance).
19. **1924. Thorne, Gerald.** Letter dated April 7th, 1924.
20. **1923. Hopkins, A. D.** Letter dated December 28, 1923.
21. **1915. Mosher, F. H.** U. S. Dept. Agri. Bul. 250, 39 p., 6 pl. 1915.
22. **1924. Quayle, H. J.** Letter dated March 12, 1924.
23. **1922. Cartwright, W. B.** Journ. Econ. Ent., Vol. 15, No. 5, pages 360–363. October, 1922.
24. **1913. Dean, George A.** Kansas Agr. Exp. Sta. Bul., No. 189.
25. **1898. Chittenden, F. H.** U. S. D. A. Year Book for 1898, p. 245.

*Since this was written in 1924, the name Southern Cowpea Weevil has been adopted.

26. **1909. Swenk.** Nebraska Bd. Agr. R. F., 1909, page 249.
27. **1919. Paddock, F. B.** and **Reinhard, H. J.** Texas Agr. Exp. Sta. Bul. 256.
28. **Pettit, H. R.** Mich. Agr. Exp. Sta. Bul. 244.
29. **1910. Pettit, H. R.** Mich. Agr. Exp. Sta. Bul. 258. 1910.
30. **1918. Back, E. A.** and **Duckett, A. B.** U. S. D. A. Farmers Bulletin 983. 1918.
31. **1918. Skaife, S. H.** D. A. Union of South Africa.
32. **1918. Bridwell, J. C.** Proc. Hawaiian Ent. Soc. for 1917, III, No. 5.
33. **1923. Kannan, K. Kunhi.** Entomological Series Bul. No. 7, Department of Agric., Mysore State.

EXPLANATION OF PLATE IV.

Fig. 1. Horse Beans of Broad Windsor, showing *a*, Eggs of 4-spotted cowpea weevil; *b*, Eggs removed to show entrance holes; *c*, Part of seed coat removed.

Fig. 2. Eggs of *B. quadrimaculatus* on lead pencils and handle of dissecting needle.

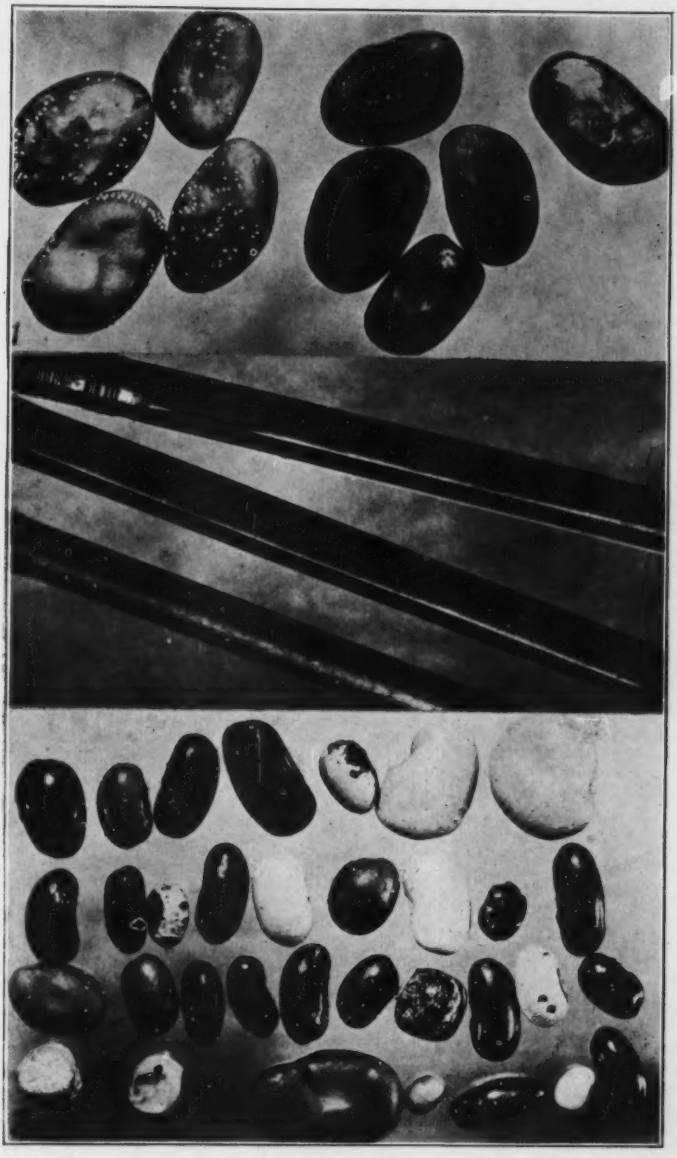
Fig. 3. Beans used in experiment to show varieties preferred by *B. quadrimaculatus* for oviposition. Listed in ascending order with reference to number of eggs laid.

Lower left: 1, Garbanza; 2, Lentil; 3, Prizetaker pea; 4, Dwarf Sugar pea; 5, Broad windsor; 6, Mammoth Yellow Soy; 7, Common bean (variety unknown); 8, Nicaragua; 9, Black Valentine.

Second row left: 10, Small Windsor; 11, Pink; 12, Burpee's Stringless Green Pod; 13, Baldwin Wonder Wax; 14, Eastern Cornfield; 15, Pinto; 16, Velvet; 17, Improved long yellow six weeks; 18, Blackeyed cowpea; 19, Mexican Red.

Third row left: 20, Kentucky Wonder Wax; 21, Red Valentine; 22, Holstein cowpea; 23, Brown Kentucky Wonder; 24, Lazy Wife; 25, Cranberry; 26, Dutch Caseknife; 27, Red Ripper cowpea; 28, Early Mohawk.

Fourth row left: 29, Italy's Favorite; 30, Bayo; 31, Red Kidney; 32, Scarlet runner; 33, Improved Golden Wax; 34, Bush Lima; 35, Fordhook Lima.



A. O. Larson

NOTES ON THE BIOLOGY OF THE MEAL WORMS, TENEBRIO MOLITOR LINNE AND T. OBSCURUS FAB.

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INTRODUCTION.

Owing to their usefulness as food for birds, reptiles, fish and small mammals, their desirability for anatomical and genetical research (for they are large in size and easily reared), and their destructiveness as pests of flour, meal, grain, etc., the meal worms have been well known for centuries. Many interesting accounts of the two species, *Tenebrio molitor and T. obscurus*, have been published, but aside from the brief observations of Riley in 1883 (6), Chittenden in 1895 (3) and 1896 (4), and Rau in 1915 (5), but little accurate information has been obtained on the biology of the meal worms in North America. Arendsen Hein, working in Europe on variations occurring in the different stages of the meal worms, made many observations on their life histories, and in 1920 (1) and 1923 (2) published valuable data on the biology of these two species. The writer has made observations on the life histories of the meal worms for the past three years and has gathered many data, some of which are presented in the following pages.

DISTRIBUTION.

The meal worms are undoubtedly cosmopolitan in distribution and have probably been introduced into every section of the United States. *Tenebrio obscurus* is occasionally reported as injurious from all parts of the country, but *T. molitor* is never reported from the southern states and apparently thrives only in the more northern states.

BIOLOGY.

At Washington, D. C., the meal worms normally pass the winter in the larval state. The adults emerge in the spring and early summer months, live for from two to three months and die. In the natural state there is, therefore, but one

full generation a year. In the laboratory an occasional individual of *Tenebrio obscurus* completed its development from egg to adult in as short a time as four months, transforming in June, July, or August instead of waiting until the following spring; on the other hand, a number of individuals of the same species required two years to complete their development, although all were reared under the same conditions. Under similar conditions no specimens of *Tenebrio molitor* completed their development in less than ten months, and slightly more than half of the specimens reared individually required two years to complete their development. When reared in an incubator with continuous favorable conditions of temperature, moisture, and food, both species bred uninterruptedly the year around and all stages were obtained at all times of the year.

THE ADULT.

The meal worm beetles closely resemble each other in size and form but *Tenebrio molitor* is shining and almost black in color, while *T. obscurus* is a dull pitchy black. Both species are nocturnal in habit and may occasionally be seen at night attracted to bright lights.

At Washington the adults normally begin to appear in the spring and from then on may be seen all through the summer. The adults of *T. obscurus* are the first to be seen, many of them emerging a month or more before the first appearance of *T. molitor*. In the laboratory, which was heated during the day in winter, adults of *T. obscurus* emerged in every month of the year. Larvæ of the first generation began to pupate as early as June, a few adults emerged in June and July, and with each succeeding month the numbers of emerging adults increased until the peak was reached in February. Adults of *T. molitor* did not begin to emerge in the laboratory until January, the peak of the emergence also occurring in February.

LONGEVITY.

Compared with many of the stored grain pests, the adults of the meal worms are relatively short lived. Statistics of several hundred specimens reared in the laboratory showed that the length of life of the female adults of *T. molitor* ranged from 37 days as a minimum to 96 days as a maximum, with an average of 65 days; the length of life of male adults ranged

from a minimum of 39 days to a maximum of 92 days, with an average of 58 days. Female adults of *T. obscurus* ranged in length of life from a minmum of 42 days to a maximum of 152 days, with an average of 84.5 days; male adults ranged in length of life from a minium of 31 days to a maximum of 132 days, with an average of 83.4 days.

OVIPOSITION.

Mating takes place within a few days after emergence and, once fertilized, the female beetles are capable of producing fertile eggs practically throughout the egg-laying period. The preoviposition period ranges from about one to three weeks, being influenced chiefly by the temperature.

The meal worm beetles are relatively prolific egg layers. Females of *Tenebrio obscurus* reared in the laboratory desposited an average of 463 eggs. the smallest number laid by one female was 73 the largest number 970. Females of *T. molitor* deposited an average of about 276 eggs each. The smallest number laid by one female was 77, the largest 576.

The oviposition period of the meal worm beetles is comparatively short when compared with other beetles infesting stored products. The oviposition period of *Tenebrio obscurus* females reared in the laboratory ranged from a minimum of 22 days to a maximum of 137 days. Similarly, the oviposition period of *T. molitor* females ranged from a minimum of 21 days to a maximum of 67 days.

The rate and frequency of oviposition varies considerably. Beetles reared in the laboratory at times made daily ovipositions for as many as 17 consecutive days, at other times there were intervals of from one to nine days between ovipositions. Occasionally but one egg was laid during a twenty-four hour period, while at other times as many as 60 eggs were laid during a like period. The greatest number laid by an adult of *T. obscurus* during a twenty-four hour period was 62, the greatest number laid by an adult of *T. molitor* during a similar period was 40. The following data will give some idea of the rate and frequency of oviposition of the meal worms: On fifteen consecutive days the number of eggs laid by a female of *T. obscurus* were 10, 0, 20, 0, 18, 0, 0, 21, 0, 0, 25, 0 20, 25, 0. For the same period another female deposited 10, 11, 2, 17, 3, 5,

15, 2, 5, 9, 4, 8, 16, 10, 12 eggs. Similarly, a female of *T. molitor* deposited 10, 0, 7, 9, 8, 13, 26, 17, 5, 0, 15, 19, 7, 0, 10 eggs on 15 consecutive days, and another female 22, 14, 8, 4, 16, 10, 12, 14, 8, 24, 14, 12, 10, 14, 2.

THE EGG STAGE

The white, oblong-oval eggs are laid singly or in small clusters, usually loosely in the flour or meal in which the insects are breeding. When first laid they are covered with a sticky secretion that causes them to become quickly coated with the particles of food in which they are deposited. The incubation period varies considerably in both species and is influenced chiefly by the temperature. With a mean average temperature ranging from 80° to 88° F., the egg stage lasts for from 4 days to a week, while with the mean average temperature ranging from 65° to 70° F., the period may be lengthened to as much as 19 days.

LENGTH OF LARVAL STAGE.

The length of the larval stage varies considerably and is influenced by several factors. At Washington, D. C., both species of meal worms normally require at least one year for development under storehouse conditions. In the case of *Tenebrio obscurus* a few larvæ that hatch in the early part of the year complete their growth and transform in midsummer, a few remain as larvæ for two years before transforming, but the majority transform at the end of the first year during the spring and early summer months. The shortest larval period observed was 79 days, covering the period from March 15, 1924, to June 2, 1924. The longest larval period observed was 642 days, covering the period from April 5, 1923, to January 6, 1925. The shortest normal larval period recorded for *T. molitor* was 281 days, covering the period from July 25, 1923, to May 1, 1924; the longest larval period recorded was 629 days, covering the period from June 26, 1922, to March 16, 1924. Of all specimens bred through in the laboratory, more than half required more than one season to complete their growth. Specimens reared in an incubator with continuous favorable conditions of temperature, humidity, and food completed the larval stage in six months.

NUMBER OF MOLTS.

The number of larval molts varies somewhat. Twelve was the smallest number of molts recorded for a single larva of *Tenebrio obscurus* during its entire period of development, while the greatest number recorded for any one larva was 22. Approximately half of all the specimens reared molted either 14 or 15 times each. The smallest number of molts recorded for a larva of *T. molitor* was 9 during the entire larval period, and the greatest number recorded for any one larva was 20. Approximately half of the specimens reared molted either 17, 18, or 19 times each.

PUPATION.

After becoming apparently full grown the larvæ may transform to the pupal form or may remain for many months with but little change in size or outward appearance.

In the laboratory at Washington, which was heated during the winter, the larvæ of *Tenebrio obscurus* began to pupate in numbers in November and continued throughout the winter and spring months. A few of the larvæ that hatched very early in the year pupated as early as June of the same year, and pupæ were obtained in small numbers during each succeeding month until November, when their numbers increased. In barns, storehouses, etc., that are unheated during the winter months, the larvæ do not pupate normally until spring or early summer.

The larvæ of *T. molitor* do not begin to pupate so early in the season as those of the foregoing species. In the laboratory the first pupæ were obtained in late January but in unheated warehouses, storehouses, etc., they do not normally pupate until May or June.

When about ready to pupate the larvæ of both species come to the surface of the foodstuff in which they are living and pass through a short prepupal period during which they are sluggish and exhibit few signs of life.

DURATION OF PUPAL STAGE

The length of the pupal stage is dependent chiefly on the prevailing temperature conditions. The pupal stage of *Tenebrio obscurus* ranged in length from a maximum of 20 days during

January and February, with a mean average temperature of 65° F., to a minimum of 7 days in June and July, when the mean average temperature ranged from 77° to 78° F. The pupal period of *T. molitor* ranged from a maximum of 18 days during February, with a mean average temperature of 65°F., to a minimum of 6 days in June, with a mean average temperature of 81° F.

LITERATURE CITED.

(1) **Arendsen Hein, S. A.** 1920. Studies on Variation in the Mealworm, Tenebrio molitor. 1. Biological Genetical Notes, Journ. of Genetics, Vol. X, No. 3, 1920, pp. 227-264.
(2) 1923. ———— Larvenarten von der Gattung Tenebrio und ihre Kultur (Col.). Ent. Mitt. XII, No. 2, pp. 121-159.
(3) **Chittenden, F. H.** 1895. U. S. Dept. of Agriculture, Farmers' Bulletin No. 45, pp. 14 and 15.
(4) ————. 1896. U. S. Dept. of Agriculture, Bur. Ent. Bul. 4, n. s., pp. 116-118.
(5) **Rau, P.** 1915. Entom. News, XXVI, No. 4, pp. 154-7.
(6) **Riley, C. V.** 1883. Amer. Nat. May (18 April), 1883, V. 17, pp. 547-548.

ANOTHER INTERMEDIARY INSECT HOST OF THE GIANT THORN-HEADED WORM OF SWINE*

Phyllophaga vehemens Horn (Scarabaeidae)

New to the Host List of this Parasite

By Robert D. Glasgow.

In the course of a search for hitherto unrecognized intermediary insect hosts of the giant thorn-headed worm of swine, *Macrocanthorhynchus hirudinaceus* (Pallas) Travassos, another step forward is marked by the discovery that *Phyllophaga vehemens* Horn is an acceptable host species for the larval development of this parasite.

Not only may the cysts of the parasite develop in *P. vehemens* grubs that have been fed upon material contaminated with eggs of the worm, but the cysts may persist through the transformation of this host species, and may probably be transported from one field to another by the flight of the infested adult beetles. In one instance, sixty-seven mature cysts of the giant thorn-headed worm were found in a single female adult of *Phyllophaga vehemens* Horn.

*Contribution from the Entomological Laboratories of the University of Illinois, Number 116.

SOME NON-NERVOUS FACTORS THAT CONDITION THE SENSITIVITY OF INSECTS TO MOISTURE, TEMPERATURE, LIGHT AND ODORS.*

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Insects are so extraordinarily sensitive to moisture, temperature, light and odors that much of our recent investigation in entomology has centered on the problems of this supersensitiveness. Just at present several large projects in economic entomology include experimentation on attractants while in other projects careful studies are being made of the correlation of possible spread with moisture and temperature conditions. All such studies presume sensitivity of insects to these factors.

The unerring and delicate response of insects to odor, light, temperature and moisture is uncanny to the human species where such reactions have become dulled as reason has developed. Male moths have been known to find the female of their species a mile away. When we figure out the physics of the problem and see what this means in the very small number of infinitesimal odor particles that must have been picked up by the chemoreceptors of the male at that distance and yet became the stimulus to move his entire body a mile, his hypersensitiveness appears nothing short of miraculous. Many insects are almost equally sensitive to quality of light. I have had stoneflies go by a three hundred candle power gas mantle lantern on the creek bank to a seventy five watt Mazda nitrogen light a half mile away, where they appeared in abundance while none appeared on my collecting sheet at the creek. Only a difference in quality of light accounts for this, the Mazda light probably giving more ultraviolet, but when we figure out the intensity of a seventy five watt light at one half mile, this reaction is in the same category of sensitiveness as that of the sense of smell of the male moth.

Sensitiveness to temperature and moisture differences is usually not so delicately developed in insects as that to odors

*Contribution from the Department of Zoology and Entomology, Ohio State University, No. 92.

and light. This difference is probably due to the fact that odor and light stimuli have to affect only the sense receptors, while temperature and moisture changes usually have to affect the condition of the whole body before becoming effective. Raising or lowering the body temperature or changing its moisture content takes an appreciable time, even if this change concerns only the surface, which makes temperature and moisture reactions noticeably slower than those to light and odor. The recent experiments of Miller and Gans[1] and of Shapley[2] on ants show that insects are very sensitive to changes of temperature. As worker ants are blind or nearly so, they make excellent subjects for the study of reaction to temperature. Insects also are very sensitive to moisture conditions which at first sight is unexpected because the impervious chitinous wall would seem an almost perfect protection against desiccation. These reactions to differences in moisture are slow but are very distinct when time enough is given as has been shown by recent unpublished work on the Mexican Bean Beetle, the European Corn Borer,[3] etc. The reaction time for temperature and moisture is so very much slower than that for odor and light that it is in a very much lower order of speed.

This general sensitiveness of insects is of a delicacy of reaction that seldom appears in the higher vertebrates. In the latter forms we recognize sensitiveness to all these factors but their reactions are less evident in that a greater range of stimuli is usually necessary to compel much change in orientation or distribution. As I shall show later, their larger size which permits warm blood and their larger and more complex central nervous system modify their behavior so that it is much more flexible.

Accompanying this sensitiveness is a pronounced rigidity of behavior so that we think of insect behavior in terms of tropisms and instincts. The insect's reactions to stimuli as compared with those of vertebrates are more direct, intense and invariable. The moth has to fly into the flame, the house fly has to come into the warm house in cool weather, the parasitic wasp has to find the host by smell. They have no choice, so that the insects have an inflexible behavior as compared with that of

[1]Miller and Gans. 1925. Jr. Comp. Psychology, V. pp. 465–473.

[2]Shapley, Harlow. 1920. Proc. Nat. Acad. Sci. VI. pp. 204–211.

[3]Huber, L. L., and Neiswander, C. R. Paper before Amer. Assn. Ec. Entomologists, Dec. 1926.

vertebrates. Neurologists and experimental zoologists have been explaining this inflexibility of insect behavior as due to its simple nervous system. This explanation is obvious and has to be granted but I wish, in this paper, to point out some factors in the insect's body structure that accentuate or actually exaggerate this sensitiveness and the accompanying rigidity of behavior.

I think of an insect as a physiological mechanism operated by various stimuli entering it through its sense organs while the intake of food and oxygen supply the power for this operation. Therefore the behavior of the insect is largely conditioned by the proportions of the various kinds of stimuli that reach the central nervous system; if dominated by light stimuli it will be heliotropic, if by chemical stimuli chemotropic, etc.

One general condition probably enters into all the types of sensitivity displayed in insect behavior. This is the extra sensitiveness due to the fact that the insect is a small animal. It appears to be a matter of the relation of surface to volume. Sense organs of one kind or another are well scattered over the surface of nearly all higher Metazoa. As the size of the animal decreases the ratio of surface to volume increases. The size of the central nervous system decreases in proportion to decrease in volume while the number of sensory cells decrease in proportion to surface so that there is a distinct tendency in small animals to have a proportionally greater number of stimulus receiving sense cells. The greater inflow of stimuli per unit of volume of the central nervous system tends to place the latter more positively under control of the stimuli entering and thus to condition a more rigid behavior. It would be difficult to actually prove this without counting the number of sense cells as compared with the total number of cells activated by them in the central nervous system, but small size is probably a real factor in increasing sensitiveness.

An evolutionary condition appears to enter into the problem also. The differentiation of sense receptors to specific stimuli and their elaboration into special sense organs was such a great step in advance in the evolution of the nervous system that it outran the evolution of compensating controls in the central nervous system in organisms of the evolutionary level of the insects. Sense organs were rather fully evolved before the necessity of controls appeared. This gave the type of insect

organism that possessed great capacity for the reception of stimuli but poor means of controlling or using them after they had entered the nervous system. In later and higher evolution various inhibiting and controlling features were added to the central nervous system that freed the organism from the dominance of sensory stimuli, thus permitting the evolution of a more plastic behavior. This has happened even, in a small way, in the higher insects such as social forms where plasticity of behavior appears. The inhibition and control of stimuli has reached its greatest development in the brain of man where nearly all stimuli are more or less under memory control.

Sensitiveness to moisture.—Insects are very closely tuned to narrow moisture limits in their environment because they are at a great disadvantage as compared with larger animals, such as the vertebrates, in the ratio of their surface to their volume. Their surface is so great as compared to their volume that they dry out more rapidly than do larger animals. This ratio favors the larger animals because the volume increases as the cube of the diameter while the surface increases as the square of the diameter. To an animal as small as an insect, which has such a large surface that dissipates moisture in proportion to the small volume that furnishes it, this matter of moisture losses becomes a very serious problem.

The difference in this matter between such a large insect as a silk-worm and as small a vertebrate as a rat is astonishing. If we assume both to be simple cylinders, for mathematical simplicity, the silk-worm to be 2 inches long by ¼ inch in diameter, and the rat to be 6 inches long by 2 inches in diameter, and if both dissipated moisture with equal speed from equal areas of their surfaces, the insect would dissipate about nine times as much moisture per unit of volume as does the rat. This is a tremendous disadvantage for the insect which, while it is compensated for somewhat by the nearly impervious exoskeleton, has to be offset in various ways before the insect can occupy any even moderately dry environment. The most outstanding adaptation to equalize the insect's chances in spite of its small size is its sensitiveness or discomfort when its minimum limit of surrounding humidity is approached. The insect becomes active until it accidentally comes into surroundings of greater comfort with increased humidity. The sensitiveness saves the individual insect.

However it does not always save the species, as a series of dry seasons may lower the humidity enough to reduce the numbers of a species very materially. Cook's[4] work on the Pale Western Cutworm has shown how series of dry years may change the distribution for hundreds of miles.

Many species are saved to dry environments by various tricks of habit and structure. In the desert and in the semi-desert or great plains, we find, first, that the great majority of insects are active only during the early spring when winter rains have increased the humidity while they aestivate in some more impervious form during the hotter and dryer parts of the year. This phenomenon has been attributed to the abundance of herbaceous food in the spring but is probably as much due to the increased humidity of that season. It is at that time that the leaf-hoppers and smaller insects are abundant. Second, a large number of desert insects are nocturnal. Bradley[5] found that a tent light would be covered with swarms of insects in deserts that harbored very few diurnal forms. Such species avoided the dry daylight air by hiding in the ground or by lowering their respiration by inactivity during the day but swarmed out at night when the lowered temperature raised the humidity. This is true also of prairie insects where humidity is low because of lack of shade. Here we find the thin skinned larvæ of various groups nocturnal, those of the Crambidae, Noctuidae and Hesperoidea especially. Third, many insects have become subterranean and thus avoid desiccation, such as the desert coccid, Margarodes[6] and various aphids, fulgorids and cercopids.[7] The desert ants dig deeper nests than do their relatives of the humid regions as has been pointed out by Wheeler[8] for the fungus-eating Atti. Fourth, certain groups of minute insects have few desert representatives though otherwise they would be expected to occur in such regions. This is particularly true of Mallophaga[9] which are

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[4]Cook, W. C. 1926. Ecology, VII. pp. 37–47.

[5]Bradley, J. Chester. 1919. Sci. Monthly, VIII, p. 362 and statements to the author by Harry Knight.

[6]Ferris, G. F. 1919. Ent. News, XXX, pp. 27–28.

[7]Ball, E. D. 1901. Ohio Nat. I, p. 122. 1909. Proc. Biol. Soc. Wash. XXII, pp. 197–204. 1915. Ann. Ent. Soc. Amer. VIII, pp. 365–368.

[8]Wheeler, W. M. 1923. Social Life Among the Insects, p. 194.

[9]David Hall, while collecting Mallophaga in Utah, found none on birds of the open desert. 1925.

seldom, if ever, found on desert birds while they are abundant on nearly every waterfowl. Fifth, many insects have developed impervious stages for long-period aestivation until favorable moisture conditions recur again. The coccid, Margarodes, has evolved a hardshelled quiescent stage, the so-called desert pearl, between the larva and the adult in which it can aestivate several years. The bombycine moth, Rothschildia,[10] has an impervious pupa or perhaps cocoon in which it has been known to aestivate as long as eight years, the individuals of the brood emerging at irregular intervals during this time when some of them strike a humid season. Sixth, the characteristic day insects of the hot deserts are usually large forms such as Acridid grasshoppers, Tenebrionid beetles and cicadas, where the ratio of surface to volume is not so disproportionate. The Odonata of the desert that fly any distance from the few humid stream valleys are large insects. The small Zygoptera stay close to the marshy spots. Curiously enough we find that the aquatic insects of the desert streams are usually specific desert species[11] so that the limits of aridity must condition the adult, as the conditions for the larvæ are the same as for larvæ of aquatic insects in mesophytic regions.

This sensitiveness to the amount of humidity runs all through the insect fauna of the mesophytic regions also. Even in these regions the number of species on the wing is greatest in May, June and the latter part of August and not during July, when light and temperature are highest and one would expect the greatest amount of activity in cold-blooded organisms. The larvæ of the August peak may be present in July but larvæ are usually in situations more humid than those the free flying adult can occupy. The lowered humidity of mid-summer, because of the increased heat, thus appears to be a seasonal barrier to the appearance of many species.

The writer has discussed this phenomenon of two peaks of occurrence during the collecting season with various men of wide experience in collecting but no one has been able to offer a satisfactory explanation of it. The usual feeling is that it is due to a two peaked coincidence of several causes, abundance of food plant, length of life-history, etc. Starting

[10]Rowley, R. R. 1923. Note, Can. Ent. LV, p. 198.

[11]The writer has found this true in Odonata, but it is true in other groups.

with the work of Shelford and Adams[12] on the great differences of humidity within relatively short distances in any general environment, we have come to recognize that this is probably one of the most important factors in the distribution of most insects. This assumption has been recently confirmed by the work of Transeau[13] and his students on the distribution of insect pests in Ohio. While these may be widely distributed, they seldom occur in numbers great enough to cause damage (in an optimum condition of existence) except in areas that follow very closely the distribution of the types of forest mapped for Ohio.[14] Plant ecologists have correllated the distribution of forest types very closely with humidity, from which we infer that the same factor probably controls the distribution of insects limited to the same areas, especially as the food plants of these insects are much more widely distributed but are practically undisturbed outside these narrow limits of humidity. If this is true, then the differences in humidity in any given environment are as great between the mid-summer and late spring on the one hand and fall on the other as between an oak-hickory association and a beech-maple or a mixed mesophytic association. This is enough of a difference to account for the two peaks of abundance of species of insects during the season.

We find that even in the mesophytic regions of relatively high humidity the minute insects, which are extraordinarily handicapped by ratio of surface to volume, are usually found in exceptionally moist situations. The moist soil is full of minute Collembola and dipterous larvæ. In fact the thin-skinned larvæ of nearly all small Diptera either are aquatic or live in very moist conditions. Outbreaks of aphids with their small size and thin chitin are usually looked for by economic entomologists during periods of humid weather. A short dry spell will completely clean up outbreaks of potato aphis.[15] The larvæ of some insects are never found except on the under surfaces of leaves where they can exist in the delicate stratum of humid air covering the respiratory surface of the leaf.[16]

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[12]Adams, C. C. 1915. Ill. State Lab. of Nat. Hist. Bull. XI, pp. 33–280.

[13]Huber, L. L., and Neiswander, C. R. 1926. Paper before Amer. Assn. Ec. Entomologists, Dec., 1926.

[14]Transeau, E. A. 1926. Paper before Ecological Soc. of Amer., Dec., 1926.

[15]C. R. Crosby to the writer concerning potato aphis on Long Island.

[16]Cutright, C. R. 1923. Jour. Ec. Ent. XVI, pp. 448–456.

The few dipterous maggots, such as Syrphid larvæ, that crawl about in exposed situations are thicker skinned than ordinary maggots and usually live in colonies of aphids which themselves occupy relatively humid surroundings. Small insects, such as Coccidae, that do live in exposed situations are usually specially adapted to these by burrowing in bark as in Xylococcus, by waxy coverings as in diaspine scales or by specially thickened body walls as in Lecanium. The latter are two separate and distinct adaptations in the same family that offset the disadvantage of ratio of surface to volume in such small insects. The many small insects that manage to live in comparatively exposed and dry situations are usually sucking insects (hemipterous) which can supply moisture dissipated in the low humidity by the constant intake of plant or animal juices. This applies especially to the numerous small Homoptera which are also well protected by a relatively thick chitinous body-wall.

The sensitiveness of small insects to amount of humidity is evidenced further by the negative evidence that all ponds and streams fairly teem with myriads of minute insects. Here they are freed from the conditions imposed by small size. Here we find the innumerable hosts of Chironomidae, Psychodidae, minute Trichoptera, Ephemerida and small Plecoptera. Futhermore, the adults of nearly all of these are nocturnal which brings the activity of the small adults into the time of day of greatest humidity. Miss Annette Braun's work on the Microlepidoptera has shown the same conditions for these minute insects. The larvæ are miners that live in moist plant tissue while the adults are nearly all crepuscular. There may enter here another factor, which will be discussed in a later paper, that of the actual crowding of these primitive types into areas and times of low metabolic activity by more modern and more active species. As an aquatic environment is no handicap to a large insect, in the matter of ratio of surface to volume, many of these are found in the water also.

The small size of the insect thus imposes on it the problem of moisture balance between its exterior and interior as the ratio of evaporating surface to the volume that supplies the moisture becomes more disadvantageous as the size of the organism diminishes.

It has been suggested to the writer that the tracheal system aggravates this situation as it penetrates all tissues and must constantly withdraw moisture. But on further consideration it does not appear that this adds any more of a handicap than does lung respiration to the larger land vertebrates, because equal respiratory surfaces, whether on a tracheole or on a lung epithelium, probably dissipate about equal amounts of moisture with equal activity of the tissues involved in oxidation. This can favor a land vertebrate only if more oxygen and less accompanying moisture can pass through a lung surface than through a tracheole wall, a point on which we have but few data.[17]

Sensitiveness to Temperature.—Insects are very sensitive to relative temperatures. The work of Shapley[18] on the ant Liometopum and of Miller and Gans[19] on Cremastogaster shows this very strikingly. Unfortunately most of the work on heat reactions of insects has been done on eyed species where the reactions to light have not been positively eliminated. Hence work, like the above, on blind worker ants gives us more reliable data. Each species of insect has a fairly definite point at which it becomes active on rising temperature or inactive on a descending temperature. This is the handicap of every cold-blooded animal. The warm-blooded vertebrates ignore the lesser changes in temperature.

This condition in insects is based on the relation of surface to volume as was the problem of desiccation. Small size prevents the animal from keeping warm by heat generated within itself. This problem is nicely stated by Haldane.[20] "All warm-blooded animals at rest lose the same amount of heat from a unit area of skin, for which purpose they need a food supply proportional to their surface and not to their weight. Five thousand mice weigh as much as a man. Their surface and food, or oxygen consumption, are about seventeen times that of a man. In fact a mouse eats about one quarter its own weight of food every day, which is mainly used in keeping it warm" If we consider an insect proportionally as much smaller than a mouse as a mouse is than man, the amount the insect will have to eat to keep warm will work out as follows:

[17]Bayliss. 1915. Principles of General Physiology. pp. 628–629.
[18]Shapley, Harlow. 1920. Proc. Nat. Acad. Sci. VI. pp. 204–211.
[19]Miller and Gans. 1925. Jour. Comp. Psychology V. pp. 465–473.
[20]Haldane, J. B. S. 1926. Harper's Magazine, March, p. 426.

The man would use food equal to one percent of his weight and the mouse the equal to twenty five percent of its weight while the insect would eat an amount equal to six hundred and twenty five percent of its weight. This would appear to be an alimentary impossibility though some slight compensation may occur in the early and late flying social insects that fly from early dawn till full darkness such as Vespa and Bremus through the concentrated and easily digestible nature of their foods that may give them enough body warmth to extend the hours of their activity. Because of the great amount of food that would be neccessary to keep the body warm, all insects are compelled to be cold-blooded which makes them exceedingly sensitive to the surrounding temperature. A few social insects such as Apis and Vespa have nests with walls of some non-conducting material that conserve the heat in their brood nurseries. A nest of Vespa is as warm as blood and is held to that temperature night and day during the brood season.

A cold-blooded existence is a tremendous handicap as it prevents activity during cold weather so that in cold regions insects lose half of their time in some manner of dormancy and are exposed during this time to the vicissitudes of unfavorable weather that each year reduce their numbers to a very low level. A warm-blooded animal is practically indifferent to moderate changes in temperature but an insect enjoys full activity only in a specific and relatively high temperature. Thus through the ratio of surface to volume insects are conditioned by their small size to sensitiveness to temperature.

This phenomenon of exact adjustment of insects to specific temperatures is so well known to entomologists that it needs little argument. However much care has to be taken in field observations on reactions of eyed insects to temperature unless checked by controlled laboratory experiments, as in Chapman's[21] interesting work on sandune insects. Here he found that each species was rather closely tuned to a specific level of temperature, below which it became inactive and above which it died, so that species after species became active as the morning temperature arose and in the afternoon became inactive in inverse series as the temperature fell. A student of mine,

[21]Chapman, R. N. 1926. Animal Ecology with Especial Reference to Insects. Part II. pp. 158–170. Minneapolis.

Mr. R. A. Hefner, found the same thing true this summer at Put-in-Bay, for insects visiting the flowers of Ceonothus.

An interesting feature of this "entomological clock", as Chapman has named it, is that the social species of Vespa, Polistes, Bremus and Apis work earlier and later in lower temperatures than do the non-social species which are largely active only during the heat of the day. The social species are attuned to hard work and long hours by the many mouths to feed at home. R. C. L. Perkins has told the writer that certain English bumble bees work all night on warm moon-light nights in June. *Vespa maculata*, to my own sad experience when collecting nests, returns home when it has become so dark that these wasps cannot be seen by the human eye but can be only heard and felt! The fact that in the temperate regions we have no very small social wasps and very small social bees such as are numerous in the tropics may be due to the necessity of moderate or large size in a social insect in order that it can fly early and late. Perhaps having to work long hours in cool mornings and evenings to feed brood prevents small species, with great disadvantage of relatively large radiating surface as compared to food intake, from entering the cooler regions. By some, at present unknown, compensation, the ants have made adjustments of small size to this social pressure. The small Halictids,[22] have been shown recently to be social but do not carry the great brood responsibility found in the more social species.

On the other hand insects are somewhat negatively thermotropic to temperatures too high for comfort. This is accentuated by the condition that few insects can cover the body surface with moisture, which by evaporation would reduce body temperatures in situations of too intense heat. The sweat glands in mammals serve this function but only a few insects, such as cercopid larvæ and the Pear Slug, have means to moisten the surface of the body and thus reduce the body temperature. Curiously enough both these insects are able to occupy rather exposed situations in spite of their very thin-skinned bodies. True also, the exudation probably serves as

[22]Stockert, E. 1923. Knowia II. pp. 48–64, 146–165, 216–247. (Since the above was put in type Dr. E. F. Philips has suggested to the writer that because flying insects have to operate at higher speed than walking insects the small ants are able to operate at lower body temperature than the small wasps and small bees.)

well for protection against desiccation and against enemies as to keep the insect cool. Apparently only insects that have immediately available large sources of plant juices can do this. We have few records in the literature of negative thermotropism in insects under natural conditions as few environments become too warm for their maximum activity. Chapman[23] has shown such conditions in sand-dune situations and the writer[24] has observed what was interpreted as such in Odonata. The ratio of surface to volume works favorably here, as many insects can live in temperatures that would be soon injurious to many mammals. Because of the relatively great surface for radiation in animals as small as insects, the heat of metabolism is radiated so rapidly that it does not accumulate to a dangerous degree in unusually warm situations.

Insects are thus small cold-blooded animals, so small that the radiating surface is out of all proportion to the volume of tissue supplying heat and so cannot oxydize food fast enough to keep the body at a regulated temperature-level high enough for continous high speed activity. Apparently, as shown previously, not enough food can be eaten for heat producing oxydation to offset the constant drain through the proportionally great radiating surface. Thus insects have become highly sensitive to changes in temperature which gives them the ability to recognize situations where there is the least difference between internal and external temperatures. They thus are thermotropic and can find situations where this loss by radiation is equalized.

In the two responses just discussed, that to moisture and that to temperature, the relation of surface to volume as involved in small size is the structural factor that has conditioned the sensitiveness of insects to these stimuli. In the two responses to be discussed, that to light and that to odors, the factors that condition sensitiveness are in the structure of the sense organs themselves, as I shall show.

Sensitiveness to Light.—Most insects with compound eyes, which includes larvæ and adults in the Exopterygota and adults only in the Endopterygota, are astonishingly sensitive to light. As pointed out in the introduction certain species

[23]Chapman, R. N. 1926. Ecology VII. pp. 416–426.
[24]Kennedy, C. H. 1925. Biol. Bull. XLVIII, pp. 390–401.

of stone-flies are attracted to a seventy five watt light a half mile away and undoubtedly many other insects are equally sensitive. Many nocturnal insects are so sensitive to light that they are thrown into a state of catalepsy in strong light by overstimulation. This overstimulation accounts for the inactivity of many crepuscular and nocturnal insects in broad day light. This occurs in May-flies. This past summer during the swarming of Hexagenia at Put-in-Bay, Ohio, these insects hung motionless during the day everywhere about the grounds and many entered the laboratories and dormitories. As the light intensity decreased at twilight, they became active but in the houses became inactive again when the electric lights were turned on. One evening in a game of bridge the lights went out. A single candle was procured so the rubber could be finished. Some two dozen Hexagenias that had been hanging motionless on the walls of the room under the glare of the seventy five watt Mazda light immediately relaxed, became fully active and flew down to the single candle on the bridge table. Until the over stimulation of the electric light had been removed the may-flies had been sitting with their front legs held rigidly in front and their cerci cocked up as rigidly behind. They had been rendered rigid by over stimulation from the Mazda light.[25] This is probably, as stated above, the condition in most nocturnal, eyed insects, though moisture and temperature are conditioning factors also.

The structural defect of the compound eye that appears to condition this overstimulation to the point of catelepsy is the great size of the compound has eye in proportion to that of the nervous system. The compound eye has to possess a certain specific size before it can give a distinct image. This is because the image, as shown by Exner,[26] is ordinarily mosaic so that the greater the number of facets the finer the mosaic of light on the retina giving thus an image more distinct and sharp in detail. But even in the largest insect eyes the image is vague, as was shown by Exner who placed a photographic plate in the place of the retina and used the compound lenses as a lens for this experimental camera. Photographs of objects thus

[25]Schmidt, P. 1919. Smiths. Rept. for 1917, pp. 501–505. Schmidt discusses "Catalepsy in Phasmidæ," and notes that it is activated from the anterior end of the insect, but does not suspect light stimulation.

[26]Exner. 1891. Physiologie der Fazettierten Augen, etc. Vienna.

obtained were hazy as though seen through a heavy fog. Dr. H. Eltringham[27] has recently made better photographs in the same manner but these are not sharp in detail. A compound eye a foot in diameter containing millions of facets would probably give an image that would compare favorably in distinctness of detail with the image in the vertebrate eye. Thus the smaller the eye and fewer the facets the coarser the mosaic of light and the more vague the image.[28] To offset this structural defect of mosaic vision the compound eye has to be as large as the insect's nervous system can operate. In insects with more acute vision, such as Odonata, Pipunculidae and male tabanid flies, the greater part of the anterior end of the insect is eye.

The structure of the mosaic retina itself accentuates the coarseness of the moasic image thus increasing the vagueness of details. Each light sensitive rhabdom is a composite of seven retinal cells so that there is but one light sensitive point to each seven cells of the retina. The field of acute vision in the vertebrate eye, on the other hand, is composed almost entirely of individual cone cells, each of which is a light sensitive point. If retinal cells are of the same order of size in the retinas of insects and vertebrates, the vertebrate retina would give a vision seven times as distinct in detail.

The great relative size of the eye does several things to the behavior of insects. First, it tends to crowd out the other distance senses, those of hearing and smell, because of the small size of the insect which is a perfect mechanism in which there are no reserves or excess tissues, no connective tissue, a body wall of a single layer of cells, no vascular system, etc. The insect is so small that to operate successfully, every tissue and organ has to run to capacity. Any excessive development of one function withdraws physiological support from some other organ. Thus in flying predators as in Odonata sight is the most valuable sense so it has been developed to the injury of the antennae and the sense of smell. The same is true of may-flies, though here some other sense would undoubtedly be equally valuable as is shown in the ecologically parallel Chironomidae which have almost the same habits of flight and mating but which possess well developed antennal senses but

[27]Eltringham, H. 1919. Trans. Ent. Soc. London.

[28]Haldane, J. B. S. 1926. Harper's Magazine, March, p. 426.

only mediocre eyes. When the eyes are so large, they draw on the nervous system for such a great amount of power to operate that other senses have to be given up. We have not usually thought of sensory cells as using much power because their fatigue does not come into consciousness but probably they use as much power per cell as do motor cells, which in the case of the compound eyes with optic tracts whose cross-sections are greater than that of any other nerve of the body must be a tremendous drain on the nervous system. Recent physiological studies[29] have shown that nervous tissue has the highest oxydation rate of any tissue of the body. Thus as in may-flies and Odonata the insect's sensitiveness to light is increased through indirection by the reduction or even elimination of other senses.

Second, the great relative size of the eyes makes the insect directly hypersensitive to light. This is due to the proportionally enormous stimulation that must pour into the nervous system through the very large eyes. All insects with compound eyes are notoriously heliotropic, positively or negatively. They are so overstimulated by light that they are held to this rigid heliotropism, as cited previously for the may-flies at Put-in-Bay. The situation is quite different in the vertebrate, where the retinal surface which receives light stimuli is relatively small in comparison to the areas devoted to the reception of other stimuli and is proportionally very much smaller in comparison to the very large central nervous system that is activated by the stimuli. The behavior or reaction of the animal is an integration of various stimuli or a balance of one against another. With the enormous area of retina in compound eyes which may cover nearly the whole surface of the head, the flood of stimulation entering the nervous system through the eye overbalances every other stimulus and activity of the nervous system simply because the mosaic eye has to be large to give a relatively distinct image. If the vertebrate eye covered the whole head we would likewise be positively and rigidly heliotropic. The vertebrate retina is so small in comparison to the amount of nervous system to be stimulated that in vertebrates this is seldom overstimulated by light. Thus, while the sight in vertebrates is adequate to give distinct vision it seldom overstimulates the general nervous system

[29]Parker, G. H. and students in recent papers.

which can develop more easily those delicate and precise reactions to the stimuli entering that condition more plastic behavior. Any one who has tried to write in a flood of light and noise can understand the effect on the internal reactions of the insect's nervous system when swamped in light stimuli. This overstimulation is compensated for in all manner of ways in insects, by pigment, by degeneration of eyes in larvæ and in forms where the sense of smell is adequate, and by movements into or out of light. However the fact remains that the insect with compound eyes large enough to form distinct images is over-eyed and over-stimulated by light, hence hypersensitive to light.

For an animal with little psychic sensitiveness the usual eyed insect is very sensitive to objects in motion.[30] This sensitiveness appears to come from the fact that an object moving across the field of vision strikes each facet in succession, delivering a series of discrete stimuli to the nervous system. A moving object for the same reason is more visible in the vertebrate eye than a stationary object, but in the compound eye the series of stimuli from a moving object are fewer in number and are farther apart in time and space and so are more effective than in the vertebrate camera eye. Vertebrate sensitivity to moving objects is probably more often accentuated by psychic responses such as fear, anger, hunger, sex, etc. One who has collected Odonata, soon learns how exceedingly sensitive these insects are to motion of the collector but how apathetic they are to him when he is stationary.

The work of Forel[31] and more recently of Lutz[32] has shown us that insects are probably more sensitive to ultraviolet rays than to the series of rays forming the spectrum visible to the vertebrate eye. No work has been done experimentally yet to determine whether this difference is due to the quality of light after passing through chitinous lenses or to a different sensitivity of the nervous light receptors. Some simple experiments with insect lenses ought to determine this. If due to the transmitting quality of the chitinous lenses, this peculiarity of sensitiveness to ultraviolet rays would fall in our category of non-nervous factors that condition the sensitivity of insects.

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[30]Imms. 1924. General Textbook of Entomology, p. 78.

[31]Forel. 1908. The Senses of Insects.

[32]Lutz, F. E. 1924. Ann. N. Y. Acad. Sci. XXIX, pp. 471–528.

Insects are thus conditioned to great sensitivity to light because of their small size and mosaic vision. The mosaic eye has to be large in proportion to the small nervous system to give a vision distinct enough to be useful. This increases relative sensitiveness to light as the large eyes crowd out other sense organs through physiological competition and increases specific sensitiveness to light by flooding the small nervous system with light stimuli.

Sensitiveness to odors.—In the sense of smell many insects are superior to vertebrates. When we realize that some moths can smell their mates a mile away[33] and that among social insects friends are recoginized by odor, we get some conception of the world of odors in which many insects live. This sense has been especially developed in insects that are blind or that have poor eyesight, as in termites and worker ants. In these the more delicate sense of smell is not overbalanced by a flood of light stimuli.

There is much doubt among experimentalists as to just how an insect detects odors. The various types of supposed organs of smell are reviewed by Snodgrass.[34] The sense of smell has been variously attributed to three types of organs, (1) hair organs divided into sensilla basiconica, sensilla coelonica and sensilla ampulacea, (2) campaniform organs and (3) plate organs, all of which appear to have been derived from simple tactile hairs. The usual theory is that the more important chemoreceptors are on the antennae, but McIndoo,[35] who has done much work on insect sense organs, believes that the sense of smell is located in certain groups of sensilla on the bases of the wings and the legs. The writer does not believe that there is enough clear experimental evidence against the older theory of an antennal sense of smell to discard it yet.[36] Undoubtedly organs of smell do occur on other parts of the body also. The writer wishes to be more or less noncommittal until the experimentalists have settled the question definitely. The fact that some insects (male honey bees) have on the antennae as high

[33]Recent unpublished experimental work shows marked moths attracted a mile by chemical baits.

[34]Snodgrass, R. E. 1926. Smiths. Misc. Coll. LXXVII, No. 8.

[35]McIndoo, N. E. 1914. Smiths. Misc. Coll. LXIII, No. 8. 1922. Smiths. Rept. for 1920, pp. 461–484.

[36]Hauser, Gustav. 1880. Zeitsch. f. wiss. Zool. XXXIV, pp. 367–403.

as 30,000 sensilla placodea (plate organs), the structure of which suggests a function as chemoreceptors will have to be explained before we can abandon the theory that the antennae are organs of smell.

However, if we follow Hauser and Forel in assuming that the antennae are the main organs of smell, certain features of their structure would help to account for the unusual development of this sense in insects. First, the antennal chemoreceptors have a relatively dry receiving surface while the sensory parts are thoroughly protected from drying by chitin which permits their exposure on the outer surface of the animal. Second, they are elevated on movable organs (the antennae) which places them in a very advantageous position for investigating odors.

The supposed chemoreceptors appear to have been derived from tactile hairs by the reduction of the hair to a thin-walled cone (hair organ), a thin-walled bell-shaped structure (campaniform organ) or to a delicate, plate-like chitinous (?) membrane (plate organs). Many stages of this evolution of chemoreceptors have been described in various insects. When we check over the limitations of this type of organ we find that the fairly dry, chitinous receptive surface imposes the defect shown by many insects of being relatively insensitive to odors in dry weather. Parasitic Hymenoptera, in the writer's own experience, can hardly be attracted to baits in dry weather while they come in large numbers in humid seasons. However such behavior might be interpreted as sensitiveness to lack of humidity.

The relatively dry receiving surface of the chemoreceptors, on the other hand, has made an organ that can be placed externally and so is more effective in locating odors than an organ placed internally as in land vertebrates.

Furthermore, the sense of smell has profited greatly by the elevation of the chemoreceptors on an external movable organ, the antenna.[37] The tubular chitinous antenna makes possible the elevation of the sensilla from the surface of the body in an organ that can be directed or placed in the most advantageous position for examining odors. Forel has pointed out the possibilities of increased discrimination open to an insect because

[37]Forel. 1908. The Senses of Insects.

the organs of smell are located externally on antennae which can be waved about in the air studying each odor, as it were, *in situ*, rather than having to distinguish odors after they had been thoroughly mixed and stirred about by being drawn into an olfactory chamber, as in land vertebrates. Forel even goes so far as to suggest that higher insects, such as ants, may have a memory for odor-forms of objects after having touched them all over with the antennae, a type of memory incomprehensible to a visual minded human being with a degenerate sense of smell.

The richness of possible reactions through chemotropism appears to have been overlooked by most writers on tropisms. It is usually classified in the same category as hydrotropism, thermotropism, heliotropism etc, whereas in point of richness of diverse chemostimuli it is in a class by itself. The range of possible stimuli in either hydrotropism, thermotropism or even of heliotropism is very small as compared to the possible range of stimuli in chemotropism. Heliotropism does become rich in possible reactions in the higher vertebrates through the evolution of an intricate brain to interpret retinal images but in organisms of the evolutionary level of insects this ability is undeveloped. In insects the number of possible chemical stimuli appears to almost infinite while in each of the other tropisms the range of possible stimuli is comparatively narrow. This puts chemotropism in an order of richness of possible reaction far above that of any other tropism, in fact, in a class by itself. This richness of kinds of odor stimuli is probably the quality which has made reaction to chemostimuli of such great value in the life of social insects which are the last and highest evolutionary insect type. Chemotropism thus appears to have been of greater value in insect evolution as the social integrant than any of the other tropisms with lesser ranges of possibilities.

We have so few data on the sense of touch in insects that it is hardly worth our while to review it.[38] Probably nearly all the movable hairs are tactile organs and some of the free nerve endings in the hypodermis may have a touch function. Apparently the hard chitinous nature of the tactile organs prevents the insect from getting any touch impression of an object other than that of its mere presence or absence. Texture

[38]McIndoo, N. E. 1922. Smiths. Rept. for 1920, pp. 461–484.

of surface of the object, its hardness, etc., probably can not be perceived. Touch may be actually lacking over large areas of smooth, hairless, hard shelled insects such as beetles and some Hymenoptera. However, it is a valuable sense in the smaller adjustments of the insect to its environment and is made use of by the thigmatropic species such as Blattidae, Aradidae, and such as hide in crevices because they are not comfortable unless both dorsal and ventral surfaces are in contact by touch with the surroundings.

The sense of hearing is very poorly developed.[39] Probably nearly all insects hear jars that are heavy enough to shake the whole organism but few probably hear any extended range of high pitched sounds such as those audible to the vertebrate ear. A small range of sound is probably audible to Johnson's organ in the second antennal joint, to Siebold's organ[40] in the tibia of Tettigoniidae and to the tympanal organ of Acrididae. The same is probably true of the sense of taste. Chemoreceptors are found on all the mouth parts and may function as organs of taste but experimental data are hard to obtain on these functions.[41]

The writer will show in another paper how nearly all conditions of insect sensitivity discussed above are imposed by the possession of an exoskeleton. This has limited the insect to small size and has made it sensitive to temperature and moisture because of the relation of surface to volume. The exoskeleton has conditioned a compound eye with mosaic vision and has made possible the development of external sensilla of smell and the development of movable antennae.

It has usually been assumed that the sensitivity of any organism to stimuli is a direct function of the nervous system.

In this review of the sensitivity of insects the author has attempted to show that, while the final sensitivity is a function of the nervous system, it is conditioned by various other structural features of the organism in question. The small size of the insect has conditioned the sensitivity to moisture and temperature. The chitinous exoskeleton has conditioned sensitivity to odors and to light while it has conditioned the quality of the sense of touch.

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[39]Forel. 1908. The Senses of Insects.

[40]Schwabe, Josef. 1906. Zoologica. L, pp. 1–154.

[41]McIndoo, N. E. 1916. Smiths. Misc. Coll. LXV, No. 14. 1922. Smiths. Rept. for 1920. pp. 461–484.

THE ROCKY MOUNTAIN SPECIES OF THE MAYFLY GENUS EPHEMERELLA.

JAMES G. NEEDHAM.

Ever since the publication in 1884 of that part of Eaton's *Revisional Monograph of Recent Ephemeridæ* treating of the genus Ephemerella, the Rocky Moutain region has been known as the source of some of the most remarkable of Mayflies. The strangest of these Eaton knew only as nymphs. These he described and figured. The incomplete results of rearings that were published by myself in 1905 and by Dodds in 1923 left matters in some confusion, as was pointed out by Lestage in his comprehensive review of the group in 1925. For some time there has been obvious need of more careful life-history work on these forms, such as could only be done in the place where they live.

In the summer of 1926 I had an opportunity, during a six weeks stay in Northern Utah, to live beside Logan River, and to rear many of the aquatic insects of that beautiful mountain stream. There I reared four of Eaton's species belonging to the Ephemerella group; and on a concluding trip to mountain streams farther southward I collected others as nymphs. For the first time material is at hand adequate for learning the identity of these curiously diverse forms.

In this group it is easy to find striking differences among the nymphs, while the corresponding differences among the adults seem trivial, and hardly of generic value. In this paper I shall treat Ephemerella as a single genus, having four subgenera in the Rocky Mountain region.* The seven species that I have obtained thence divide into four groups as follows:

* This omits Chitonophora Bengtsson (1909) and Torleya Lestage (1917), because I cannot fit the American species to the combination of characters given in the definition of these very minor groups. It may be worthy of record here that Ephemerella nymphs of the Torleya type as described by Lestage, having compact bodies and stout, bristle-whorled tails, occur also in America. I have some specimens that were collected in 1923, in San Antonio Canyon, near Claremont, California, by Miss Theresa M. Robinson.

KEY TO THE SUBGENERA OF EPHEMERELLA.

Adults.

1. Intercalary veinlets between veins Cu_2 and 1st A conjoined into two strong forks that are attached basally to the former.....2
   These intercalaries weak and in part unattached basally...**Ephemerella** Walsh.
2. Veins Cu_2 and 1st A usually conjoined basally by a cross vein (sometimes touching at a single point); ♂, inner margin of long 2nd joint of forceps gently curved; ♀, 9th ventral segment bilobed at apex.....**Drunella** Ndm.
   Veins Cu_2 and 1st A fused for a distance basally; ♂, inner margin of 2nd joint of forceps angulate; ♀, 9th ventral segment of abdomen entire at apex, **Eatonella** n. subg.

Nymphs.

1. Head with a broad frontal shelf.....2
   Head with no broad frontal shelf.....3
2. Frontal shelf entire; body flat, hairy.....**Timpanoga** n. subg.
   Frontal shelf notched at sides for reception of the antennæ; body plano-convex, smooth.....**Eatonella**
3. Head with high dorsal spines or tubercles.....**Drunella** 4
   Head with low dorsal spines or none.....**Ephemerella** 5
4. Mesothorax with no dorsal spines.....**E. grandis** Etn.
   Mesothorax with high dorsal spines.....**E. spinifera** sp. n.
5. Front femora toothed on front edge.....**E. coloradensis** Dodds
   Front femora not toothed on front edge.....6
6. Gills on abdominal segments 3–7; 2nd joint of antenna black..**E. inermis** Etn.
   Gills on abdominal segments 4–7; 2nd joint of antenna pale..**E. margarita** sp. n.

Ephemerella grandis Etn.

I especially desired to find and rear this species because of the doubt existing as to the identity of the nymph. So I was glad to find it common in Logan River. I reared thirteen specimens on eleven different dates ranging between June 18th and July 18th. Nine of these were males and four were females. About half of them are fully matured, finely colored specimens.

Neither imagos nor subimagos were seen at large.

It is the adult, rather than the nymph that is in need of completer description, since the male has not been made known, and Eaton's figures of the nymph leave, for that stage, little to be desired.

Adult male.—Length 14 mm.; tails 19–21 mm. additional.

Color of body dark brown above and below, phalerate with paler on most of the sutures. Abdomen conspicuously ringed with paler, and with pale lateral line, and a pale apical border across the 10th segment. Fore legs brownish, becoming paler towards the tip of the tarsi. Other legs all pale, except for a wash of brownish on femora beyond their bases. Tails blackish at base gradually becoming paler toward their long and very slender tips.

Body very stout. Wings hyaline, principal veins dark brown. Crossveins obsolete in the costal, subcostal and basal part of first radial spaces, heavy along the middle of the wing. Generally there is a crossvein joining the base of vein Cu_2 with the 1st anal vein, but occasionally a slight fusion of the two veins occurs at this point, eliminating the crossvein.

Abdomen slowly tapering. The ninth segment bears a short, sharply triangular lateral spine that is about as long as the forceps basis, and there is a trace of a spine in corresponding position on segment 8. The basal joint of the forceps is much wider than long; the second joint is long, smoothly curved and widened to both ends; the third joint is blunt, incurved and about a fourth as long as the second. The penes are unarmed, fused together, parallel sided, with a wide V-shaped apical notch between their apices.

The subimago is similar, but duller in coloration, and on the wings a bit darker owing to heavier pigmentation along the veins.

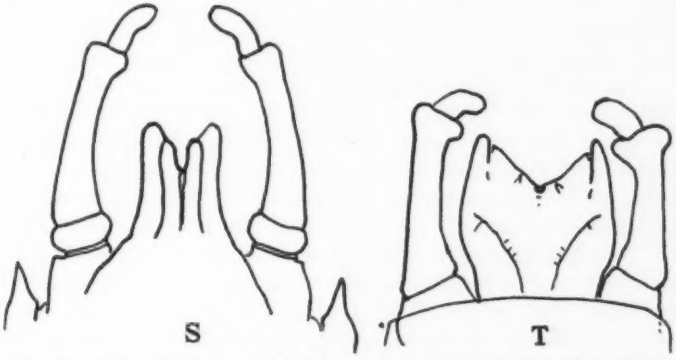


FIG. 1. Male genitalia: *S*, of *Ephemerella grandis*, and *T*, *of E, inermis*.

The statement in Eaton's description of the female, "Ventral lobe of segment 9 emarginate; the pleural points short and acute", leaves no doubt as to the identity of this species.

Eaton was right in considering the basal fusion of vein Cu_2 and 1st A in this species unusal (Monograph. p. 330) I was in error (1905, p. 43) in saying that he described it as characteristic of the species. I find that it occurs in but one of my adult specimens, and on one side only in that one. It was misleading that the single nymphal wing I then had for examination showed that fusion. However, when this fusion occurs, it is limited to a single point; whereas, in the species that Dodds (1923) reared and took to be *F, grandis*, the two veins coalesce for a short space.

The nymph of this species was adequately illustrated in Eaton's Monograph Pl. 38, Figs. 11 to 13. A few supplemental descriptive notes may be added here.

The length of grown specimens is 12.5 mm., with tails 7 mm. additional.

The coloration is usually obscured by the darkening of age and accretions of silt; but recently moulted specimens show an uneven pale middorsal line the entire length of the body, much widened on the 8th abdominal segment, and the lateral spines of the abdomen also pale. Legs broadly but obscurely ringed with brown, two rings on each femur and one on each tibia. Tails alternately brown and yellow at about six unequal intervals of each color; their joinings are sparsely beset with fragile, deciduous hairs.

The pale antennæ are shorter than the head is wide. Underneath the prothorax between the bases of the fore legs there is a flat hoof-shaped tubercle adjacent to the rear of the head. The dorsal tubercles are well developed. The stout pair on the top of the head has a backward slant. The rounded pair on the top of the prothorax has a smaller supplemental pair behind it, and the tubercle on each side of the prothorax has a smaller supplementary one before it. The paired, sharp, thorn-like, backward curving tubercles on abdominal segments 2 to 9 are longest on segments 8 and 9, but the length is increased gradually from segment 2 onward. The thin, flat, sharp lateral spines on segments 3 to 9 begin obscurely and increase in length to the 8th segment. On the narrowed 9th segment they are straghter, less incurved, but about as long as on the 9th. The 9th sternite is bilobed apically in the female; four-lobed in the male.

Besides the specimens from Logan River and those from Pecos, N. Mex., described by me in 1905, I have others from Santa Fe, N. Mex., collected by P. B. Paul and from Twin Lakes, Colorado, collected by Chancey Juday. Clemens records the occurrence of the genus in Ontario.

Ephemerella spinifera n. sp.

This is a smaller species than *D. grandis*, and with a much more remarkable development of spines upon the back. Only the nymph is known.

The nymph apparently grown measures in length 8 mm.; tails 5 mm. additional.

Color pale brownish with hardly a suggestion of pattern, though there is a succession of somewhat lighter areas on the tails. The head and body bear tubercles as follows: a huge pair on the top of the head, nearly doubling its height, aslant backwards; a smaller slender twin pair on each side of the pronotum; four pairs on the mesonotum, the median one of these largest, very prominent, aslant backward, two small sudmedian pairs, one at the front and one at the rear, the latter smallest and confluent, and outside the anterior pair is the fourth pair which is slender and of intermediate height. Then on the abdomen there are eight pairs, representing, the usual double line of dorsal hooks. These are on segments 2 to 9. They are all thorn-like, sharp-pointed and curved backward. They are subequal on segments 2 to 7, and on 8 and 9 they are three times as large and beset with scattered fragile bristles.

The pale antennæ are about as long as the head is wide. The front femora are swollen, widest across the basal third, carinate and broadly lobed in front, and carinate also above, where fringed with fragile setae. The "thumb" of the front tibia is two-fifths as long as the tarsus. There are flat lateral spines on abdominal segments 3 to 9, minute on 3 and gradually increasing in prominence to 7, 8 and 9. Gills on segments 3 to 7 in a regularly overlapping series.

Four nearly grown nymphs from Blackfoot River near Potomac, Montana, collected on June 20th, 1906 by Frank C. Barry, and a single younger nymph collected by myself in the north fork of Ogden River, Utah, on July 27th, 1926.

I have another nymph that will go in the subgenus Drunella, sent me by Chancey Juday, collected by him in the South Fork of the Keweah River, California, July 13, 1904

Ephemerella doddsii n. sp.

This is a species of large size that is known to some of the fishermen on Logan River as the "Ginger quill". In superficial appearance it is strikingly like *E. grandis*, despite remarkable differences in their nymphs.

Dodds reared a single specimen; and, finding in the wings a basal fusion of veins Cu_2 and 1st A, he naturally referred it to the only species in which that fusion was then known to occur, *E. grandis*. He published good figures of the nymph and of the gentalia of the male imago, and gave an excellent account of its habitat and habits.

The nymph is altogether unique in having developed out of the under side of the broad abdomen a powerful sucking

disc by means of which it can stoutly adhere to the surface of smooth stones in the current. This disc adheres so firmly that a sudden pull on a leg will break the leg off before the disc will let go; but the nymph may be pushed about over a smooth surface without releasing the disc, and it probably creeps by means of the disc.

The species is common in Logan River. I reared fourteen specimens on five different dates between the 19th and 28th of June, and collected at large eight others as subimagos, two of which were reared to the full adult condition. The subimagos were all taken as they flew from the river at nightfall. No imagos were seen at large.

The adult measures in length of body, ♂, 13 mm., ♀, 14 mm.; tails, ♂, 11 mm., ♀, 14.5 mm. Fore leg, ♂, 12.5 mm., ♀, 8 mm. Fore wing, ♂, 14mm., ♀, 14.5 mm.

Adult male.—Coloration strikingly like that of the preceding species, brown, with paler sutures, giving a phalerate appearance to the sides of the thorax and a ringed appearance to the abdomen, whereon runs the same pale midlateral line and border around the apical margin of the last segment. The tails are notably shorter, but have the same dark bases and pale slender tips. The dark fore legs grow graually paler toward the tips of the tarsi, and the brown on middle and hind legs is less extended than in *E. grandis*.

The wings are similar except for a constant and more extended fusion of vein Cu_2 at base with the 1st anal vein.

The lateral spines at the apex of the 9th segment are much larger, and reach the level of the base of the 2nd segment of the forceps. Basal segments of the forceps as wide as long; 2nd segment constricted and bent, almost angled, in the middle; 3rd segment blunt, about a third as long as the second.

Adult female.—The female is much paler than the male but shows a similar color disposition on the sides of the body, legs, wings, and tails. Except at its ends the abdomen appears wholly dark, due to contained eggs. The entire top of the thorax is pale tan color.

On the lateral margin of the abdomen segment 8 is angled at the apex and 9 bears a sharply triangular lateral spine that extends backward as far as the apex of the 10th segment. The apex of the 9th sternite is produced beyond 10 into an oval, entire lobe.

The subimago is similar in appearance but paler of body and darker of wing, the veins of the wing being heavily shaded with fuscous.

The nymph measures in length 11.5 mm.; tails 4 mm. additional.

The nymph of this species, also, was adequately illustrated in Eaton's Monograph, plate 39, figs. 1-22. This species totally lacks dorsal spines. It is altogether unique in the broad

frontal shelf on the head notched at the sides for the reception of the antennae and in the broad sucking disc that is developed beneath the abdomen.

The back is smooth, broadly rounded, the body being plano-convex. The color is yellowish or tan, darkening on the eyes, on the wings, on the gills, and the bases of tarsi and tails; also some pigment tends to overspread the middle of the terminal abdominal segments, but there is no definite color pattern.

Besides the specimens from Utah, I have nymphs that appear to be the same species from Potomac, Montana, collected by F. E. Barry; from Yellowstone Park, collected by R. Muttkowski; from South Fork of Keweah River, Califorina, collected by Chancey Juday; and from Goat Creek, Ashford, Washington collected by Miss Hortense Butler.

These two species, *E. grandis* and *E. doddsii*, form a remarkable pair. Here are two forms so alike in the adult stage as to be easily mistaken the one for the other, their nymphs totally unlike in appearance. The one nymph represents the highest development of spines upon back; the other, the extreme of smoothness. The one is black and dirty; the other, yellow and shining. The one clings by feet only; the other, by a highly developed ventral sucking disc.

The one lives in the edges of the stream, the other out in the swift current.

Ephemerella coloradensis Dodds.

This species was so adequately treated by Dodds (1923, p. 97, Pl. 8, Figs. 3 and 4, and 1924, p. 146,)* that I have only to add a few local notes. It is one of the commonest species in the rivers of Northern Utah, especially in their upland reaches, above 5,000 feet.

I have nymphs , also, from Yellowstone Park, Wyo., collected by Paul R. Needham; from Pecos, N. Mex., collected by Professor T. D. A. Cockerell; and from Volcano Co., Calif, collected by Chancey Juday.

On examining the stomachs of three native trout taken near the head of Logan River at about 7,000 feet, I found that this species made up about half of their food.

* Dodds does not note that Eaton had already figured the nymph of this species in his Revisional Monograph (Plate 38, Figs. 1–10).

Ephemerella inermis Etn.

This species was very common in all the streams of Northern Utah, associated with the preceding one. I reared fourteen specimens on five different dates ranging from June 25th to July 29th, and have fully matured males and females that seem to agree well with Eaton's description of the adult. I present a figure of the genitalia of the male and a description of the nymph. This is Dodds' Ephemerella nymph No 2.

The grown nymph measures in length 9 mm.; tails 4 mm. additional. Color very variable; blackish, often reddish brown, sometimes with indications of a middorsal pale line. Pale specimens show extensive mottling of the dorsum in a complicated pattern of curved pale markings upon the brown of the thorax and of dots and dashes upon the abdomen. The antennæ are pale except for a black second segment and a slight darkening of their slender tips. Legs dark, with three obscure rings of paler on each of the principal segments. Tails obscurely marked in five or six alternating areas of brown and paler.

The head is without tubercles above and the front femora are smooth. The front tibia is prolonged at apex in only a very small rounded lobe. Under the claw are eight to ten close set teeth.

The abdomen has no dorsal tubercles or hooks, but in their place is a double row of pale dots, one pair on each segment. There are the usual thin flat lateral spines on segments 4 to 9, increasing in length and sharpness on 4 to 8, less pointed on the narrower ninth segment. The gills on segments 3 to 7 are regularly overlapping. The joints of the tails are ringed apically with a whorl of short spinules and thickly fringed with slender pale hairs.

I have nymphs of this species collected by John T. Needham in The Yellowstone Park, August 8th, 1921.

Ephemerella margarita n. sp.*

This pretty nymph I did not find in Logan River but it was common farther southward. I collected it in Box-Elder (Brigham) Canon, in Weber River at the Devil's Slide, at Wanship, and at several points along Provo River where it was most common, especially in the upper reaches of that stream. These places, being visited only at the time of my departure from Utah, I had no chance to rear it. Only the nymph is known.

It superficially resembles the nymph of the preceding species being of the same slender graceful form, but it lacks

* Named for little Miss Margaret Hawley, of Salt Lake City.

gills on segment three of the abdomen, it has a single conspicuous cross band of black across the middle of the tails, its color pattern is different and its antennæ are wholly pale.

The fullgrown nymph measures in length 9.5 mm., and tails 2 mm. additional.

A slender prettily colored nymph with smooth thorax, and depressed, thin-margined abdomen. Color brownish olivaceous, with distinct blackish markings as follows: a median blackish spot on segments 2 and 3, another one on segments 5 and 6; a black streak across the apical margin of 8. Segment 9 wholly blackish above except its pale lateral spines and a pair of included submedian apical pale dots. Tails black and white; the black forming a bar across the middle and covering the tips, where it is less distinct. Legs pale, with dark bands on middle of tibiæ and tarsi and on tips of tarsi.

The head is smooth above. The front femur is entirely smooth. The front tibia bears no "thumb" but only a slight triangular prolongation beside the base of the tarsus. The claw is armed beneath with half a dozen slender teeth in a graduated series, the distal one longest.

The usual double row of dorsal hooks is represented by minute paired spinous tubercles. The lateral spines on abdominal segments 4 to 9 are thin flat, sharp and transparent, broadest on segment 7, where the abdomen too is broadest, and longest on segment 9. The gills are incompletely operculate.

This is the most generalized member of that group of species which has the gills beginning on the 4th abdominal segment with an operculate pair. The next following, *E. hecuba*, is the most specialized of that group. The two species occur together in Provo River.

Ephemerella hecuba Etn., (Hagen Ms.)

I much regret that I found this remarkable species only as I was leaving Utah and had no chance to rear it. The nymphs were grown and some of them fully ready for transformation as shown by the blackening wings. I found it only in Provo River where that stream washes the southern base of Mt. Timpanogas.*

Eaton's detailed figures of this species were made from a single cast skin. They adequarely represent structures. A few additional descriptive notes on color, made from whole nymphs, may now be added.

* I have taken a liberty with the name of that magnificent mountain, abbreviating it to make a convenient and euphonious subgeneric name.

The full grown nymph measures in length 14 mm.; tails 6 mm. additional.

Under the general covering of silt that is held by the long soft hairs that everywhere clothe the dorsal surface a few markings of darker brown may be discerned, varying the general color of light brown or tan. Blackish rings cover the basal half of all the tarsi, and faint rings are on the middle of each tibia, with sometimes a suggestion of two more upon each femur. There is a broad band of black crossing the tails at two-thirds their length, and there are one or two very narrow black rings crossing them near the base; usually, one on the middle tail and two on each of the laterals. Eyes and wing cases become blackened toward maturity. The lateral spines of the abdomen show a pale area before their sharp brown tips.

On the smoothe flat ventral surface of the abdomen there are more or less distinct bands of brown crossing the basal half of the segments.

Numerous specimens were collected in the Provo River on the 20th of July by Dr. H. J. Pack and myself. They were found clinging to the waterworn cobble stones in the edges of the stream, and not out in the current. They are utterly helpless when dislodged from the stones. They do not attempt to swim but sprawl stiffly and if overturned bend the venter convexly upward displaying the brownish crossbars of the underside.

This is the nymph of which in 1905 I published a rather poor photographic figure that was copied by Lestage in 1925 (p. 236). It represents the extreme of flattening and widening of the abdomen and lengthening of lateral spines: but it does not deserve to stand apart from the others so far as in Lestage's key; for it is only a specialized member of that group of species to which *E. margarita* belongs—the group that lacks gills on abdominal segment 3, and that has a single band of blackish color across the middle of the tails.

I have a specimen of it that was collected for me by my son Paul R. Needham in the Lanier River, Yellowstone Park, Wyoming, on August 8th 1921.

I have a nymph of still another species of Ephemerella from the Rocky Mountain region. It has high dorsal hooks on the abdomen, like a Drunella, but has none on the head or thorax. I have but one specimen and that broken. It comes from Big Blackfoot River, Potomac, Montana, and was collected there by Frank E. Barry on June 29th 1906. The tails are lacking, and all but one (hind) leg. The paired dorsal hooks on abdominal segments 3 to 9 and very long and slender, adding

about a third to the height of the abdomen. Their backwardly directed tips are sharp pointed. In front they stand erect, but gradually they incline backward until on segment 9 they point straight to the rear. The abdomen is marked with a heavy pattern of brown in three rows of large spots that lie upon the bases of the segments, one row mid-dorsal, and two lateral, largely covered by the gills. Broadly U-shaped transverse bars extend across the ventral side of the segments. All these spots widen to rearward, segment 9 being mostly brown. The gill plates on segments 3 to 7 extend obliquely toward the mid-dorsum, and are scarcely overlapped except the last pair which is smaller and paler. Around the bases of the legs are some more obscure brownish areas.

Figures of all these Utah nymphs that have not already been figured by Eaton and Dodds will be published shortly in a bulletin from the Utah Agricultural Experiment Station.

BIBLIOGRAPHY.

Dodds, G. S. 1923. Trans. Amer. Ent. Soc. 49:95–99, pl. 8.
———. 1924. Ecology 5:137–148, 2 plates.
———. 1924a. Ecology 5:262–271.
Eaton, E. A. 1884. Trans. Linn. Soc. Lond. (2) 3:124–134, plates 37–40.
Lestage, J. A. 1925. Ann. Biol. Lacustre 13:227–322.
Needham, J. G. 1905. N. Y. State Mus. Bull. 86:41–47. Pls. 9 and 10.
Ulmer, G. 1920. Stett. Ent. Zeit. 81:118–120. Drunella, p. 119.

THE EFFECT OF MONOCHROMATIC LIGHT ON FORMICA DAKOTENSIS SPECULARIS (EMERY).

C. E. Abbott.

Introduction.

Early attempts to study the color-vision of insects often led to erroneous conclusions. The absurd tests made with pieces of colored paper remind us how meager must have been the knowledge of the physics of color possessed by many experimenters in the past. As late as 1912, Seitz (4), in his own field a thoroughly competent entomologist, published a short paper that displayed a profoundly poor knowledge of physical optics.

But Lubbock (2), long ago, made reliable tests on the color-vision of insects. He had no way of equalizing the intensity of different sourses of light, but he overcame the

difficulty by varying the absorbtion of his filters and taking averages of these results. The spectral range of his filters was carefully determined. He worked much with ants, and while his results differed somewhat from mine, the species of insects tested also differed in the two cases. Lutz (3) has recently confirmed and extended many of Lubbock's conclusions. We are now beginning to employ more exact methods of research than those of Lubbock. Such methods have been exemplified by the work of Gross (1) on various arthropods. The methods employed in the following experiments have been as exact as limited time and improvised apparatus would permit.

Results.

Under this head only the numerical data are given. Four definitely determined light intensities and four color filters were used. White light was also tried. Five tests for each filter at each intensity were taken as indicated; the averages made from these were accepted as final values.

White light	72. (red)	73. (yellow)	74. (green)	75. (blue-green)
2 cm.	2 cm.	2 cm.	2 cm.	2 cm.
45 minutes	12 minutes	20 minutes	55 minutes	30 minutes
20 "	15 "	10 "	45 "	30 "
25 "	40 "	20 "	11 "	30 "
10 "	22 "	10 "	5 "	15 "
11 "	15 "	8 "	20 "	15 "
22.2 average	28 average	13 average	27.2 average	24 average
3 cm.	3 cm.	3 cm.	3 cm.	3 cm.
16 minutes	8 minutes	10 minutes	19 minutes	15 minutes
11 "	7 "	10 "	14 "	15 "
5 "	10 "	11 "	15 "	15 "
8 "	8 "	5 "	10 "	4 "
5 "	8 "	6 "	12 "	6 "
9 average	8.2 average	8.4 average	14 average	11 average
4 cm.	4 cm.	4 cm.	4 cm.	4 cm.
3.5 minutes	7 minutes	2.5 minutes	3.5 minutes	5 minutes
6 "	11 "	4.5 "	6 "	10 "
7 "	8 "	6 "	7 "	8 "
6 "	16 "	4 "	6 "	4 "
4 "	9 "	7 "	4 "	7 "
5.3 average	10.2 average	4.8 average	5.3 average	6.8 average
5cm.	5 cm.	5 cm.	5 cm.	5 cm.
3 minutes	5 minutes	2.5 minutes	3.5 minutes	4 minutes
4 "	7 "	3 "	7 "	4 "
5 "	6 "	3 "	7 "	6 "
5 "	12 "	4.5 "	10 "	6 "
8 "	10 "	5 "	1 "	7 "
5 average	8 average	3.6 average	7.9 average	5.4 average

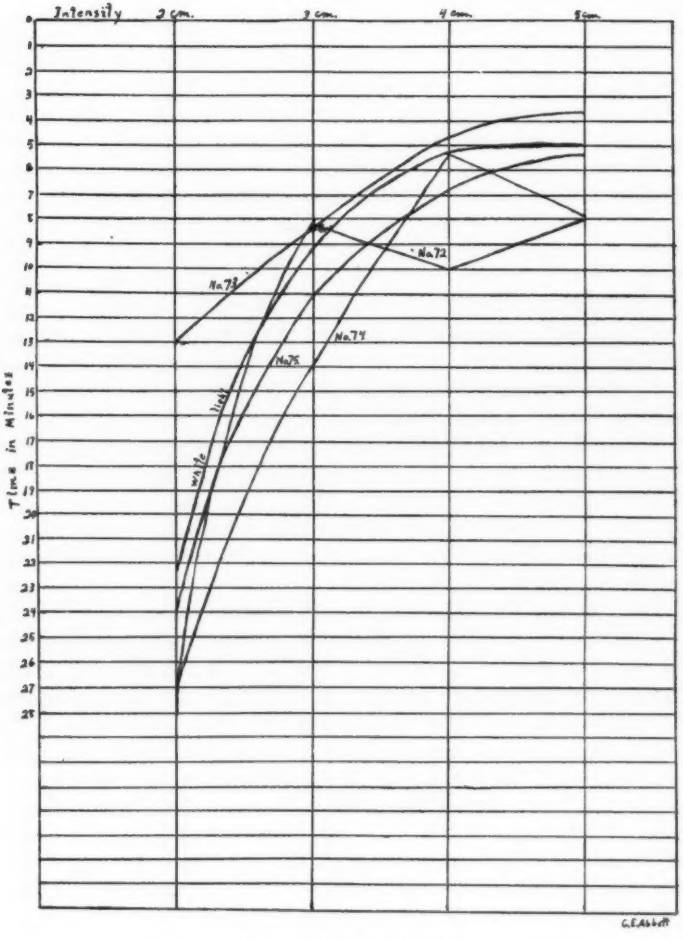
Discussion.

These experiments were performed in August, 1925. Advantage was taken of the fact that *F. dakotensis specularis*, like most ants, carry their exposed pupae from the light into the dark. The insects were kept in a large artificial nest surrounded by a moat filled with oil. The interior of this nest was made of plaster of Paris, and contained several circular depressions about two inches in diameter and about one-fourth inch deep. A glass plate completely covered the nest at the approximate height of one fourth of an inch. The ants kept the pupæ chiefly in the depressions. For each experiment one of those was chosen that had its floor completely covered with a single layer of pupæ. The length of time the ants required to remove the pupæ when light of a given color and intensity fell upon them, was considered inversely proportional to the stimulating value of the light employed.

The colony remained during the whole series of experiments in a room that was perfectly dark excepting at the time that the experimental light was used. The room was so constructed that the temperature, by actual measurement, rarely varied from 23° C. Even when variations in temperature did occur, they were always less than 1° C.

The source of light was a 100 watt incandescent bulb mounted on a wooden block and contained in a wooden box 40 x 8 x 8 inches. The block, as well as the affixed bulb, could be raised or lowered by means of a pulley. A hole two inches in diameter allowed the passage of the rays employed. The entire machine was supported at a constant height over the nest, but could be moved so that the light could be used in any part of the colony. A water-cell one inch thick prevented the transmission of infra-red. A ground-glass plate increased the diffusion. The various layers of glass through which the light passed excluded the ultra violet. The colors were obtained by the use of Wratten filters manufactured by the Eastman Kodak Company. They are catalogued as No. 72 (red), No. 73 (yellow), No. 74 (green), and No. 75 (blue-green). They are probably as nearly monochromatic as any filters that can be obtained.

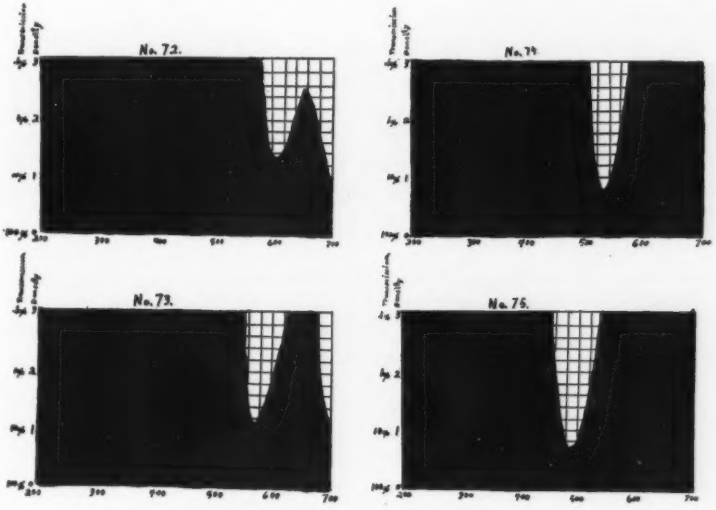
To obtain light of a given intensity a Coblentz thermopile and a Leeds and Northrup galvanometer, connected in series,



TRANSMISSION OF FILTERS.

Horizontal numbers represent spectroscope readings.

were used. The height of the bulb was varied until the desired reading appeared on the galvanometer scale. The position of the block was then marked on the side of the box; next to this mark the galvanometer reading and the filter employed were indicated. All that was needed to obtain the same intensity at another time was to use the appropriate filter and to shift the block until it was flush with this mark. In this way the various intensities for each filter as well as for white light, were controlled.



Reactions of *F. dakotensis specularis* to light.

Graphs giving the percentage of transmission and the color values of the filters accompany this paper. They are copied, with permission, from the bulletin published by the Eastman Kodak Company.

Conclusions.

The accompanying graph indicates all the results of these researches. The terms used need no explanation. It seems, from the results, that what appears to the human eye as yellow has the greatest stimulating value of any of the colors used

for *F. dakotensis specularis*. White light is second only to yellow. Lubbock's ants were most sensitive to green. It is also evident that the stimulating value of light at different intensities, irrespective of its color, is a more or less characteristic curve approaching a constant value. The irregular results with the green and red filters may possibly be explained by insufficient data; otherwise they remain a mystery. The ants reacted to white light exactly as they did to the colors. Their reaction to red may be explained by the fact that filter No.72 transmitted some yellow. It is improbable that the insects would react to pure red.

In closing, I wish especially to thank Mr. Hampton of the Botany Department of the University of Wisconsin for the use of apparatus and for various information. Thanks are also due Dr. W. M. Mann of the Bureau of Entomology for the identification of specimens, and to the Eastman Kodak Company for permission to reproduce graphs. I also am obliged to Dr. L. E. Noland for various favors.

BIBLIOGRAPHY.

1. **Gross, A. D.** Jour. Exper. Zool. XIV, 1913. p. 467.
2. **Lubbock, Sir J.** Ants, Bees, and Wasps. London, 1881.
3. **Lutz, F. E.** Ann. N. Y. Acad. Sci. XXIX, 1924. pp. 181–283.
4. **Seitz, A.** Trans. Internat. Cong. Entom. II, 1912. p. 898.

NORTH AMERICAN SPECIES OF POLYMEDON. (DIPTERA DOLICHOPODIDÆ).

M. C. Van Duzee,
Buffalo, N. Y.

The genus *Polymedon* was described by Osten Sacken in Western Diptera; Bull. of the United States Geological Survey of the Territories, iii, 317, 1877. Up to the present time all the species described have come from America. Dr. Becker described *longifacies* from South America and Dr. Aldrich described *superbus* from St. Vincent, W. I. The remaining eight forms are all from North America.

The genus is very nearly related to *Tachytrechus*, differing from that genus in having the face greatly elongated, especially in the male, extending considerably, somtimes very greatly, below the lower corners of the eyes; the lower part forming a thin plate or ribbon, which hangs down over the proboscis.

The habits of these flies are about like those of the *Tachytrechus*, they are found on stones in streams or about water falls. Four species have been found in the deep canons of Arizona, three of them in the Grand Canon.

Table of Males.

1. Femora black....2
   Femora yellow....3
2. Antennæ reddish on underside....**flabellifer** O. S.
   Antennæ wholly black....**angustatus** Ald.
3. Costa greatly enlarged before the tip of first vein....4
   Costa scarcely enlarged....5
4. Hypopygial lamellæ with two projections, one short, the other long and with a few long pale hairs at tip....**nimius** Ald.
   Lamellæ with three projections, the short blunt one on one side, a little longer one on the other side, with a sharp point at tip, and a still longer one in the center, which has a few long pale hairs at tip and many flattened, blunt ones towards the base....**dilaticosta** new species
5. Hypopygial lamellæ small, triangular....**triangularis** Ald.
   Hypopygial lamellæ larger, quadrangular....**superbus** Ald.

Table of Females.

1. Femora black....2
   Femora largely yellow, or wholly yellow....4
2. Tibiæ black....**flabellifer** O. S.
   Tibiæ yellow....3
3. Antennæ wholly black?....**argentatus** Ald.
   Antennæ yellow below....**nigrifemoratus** new species

4. Middle and hind femora with a blackish stripe on lower surface, **castor** Wheeler
   Femora wholly yellow, or a little darkened above at tip....5
5. First and second antennal joints wholly yellow....6
   First and second antennal joints narrowly black above....7
6. Middle and hind coxæ yellow with a blackish streak on outer surface. Length, 3.5 mm....**nitidus** new species
   Middle and hind coxæ black except at tip and on inner side. Length, 5 mm., **triangularis** Ald.
7. Face reaching nearly its width below the eyes....**castor** Wheeler
   Face reaching but little below the eyes....8
8. Face rounded below....**dilaticosta** new sp.
   Face ending in a point below....9
9. General color of thorax and abdomen deep blue, verging into green, **superbus** Aldrich
   General color of thorax and abdomen green, not at all blue...**nimius** Aldrich.

Polymedon dilaticosta new species.

Male: Length 5 mm.; of wing, 6 mm. Face and front silvery white, the former extending nearly twice its width below the eyes. Antennæ with the first joint long, first and second joints yellow, narrowly black on upper edge; third joint short, oval, brown with a yellow spot below; arista thick, as long as the antenna. Orbital cilia yellowish white, about eight of the upper ones on each side black.

Dorsum of thorax and abdomen shining green, sides of the former and spots on the sides of the segments of the latter with silvery white pollen; hairs of the abdomen black. Hypopygium pedunculate, black, yellowish below; lamellæ rather large, brown, paler at base, they have a slender stem and three angles, a short, blunt angle below, one a little longer above that has a sharp point at tip; a still larger one in the center, they have several long, delicate, pale hairs near the tip and many rather long, flattened, blunt ones on basal portion. One black propleural bristle above fore coxæ.

Fore coxæ yellow, with silvery white pollen, a few minute pale hairs and several black bristles at tip. Middle and hind coxæ black with yellow tips. Femora and tibiæ yellow; posterior pair of both a little brown at tip. Hind tibiæ with about seven large bristles above, a row of small ones on upper posterior edge of apical half and a row of very small ones on lower surface which are not much more than hairs with three larger ones in the row. Middle and hind tarsi black from the tip of first joint, posterior pair black almost to their base, their first joint with a small bristle below near the base; fore and middle tarsi both with a row of bristle-like hairs below. The bend between second and third joints of middle tarsi found in the male of several species is conspicuous in this form. Joints of fore tarsi as 51–17–14–12–13; of middle ones as 71–32–23–16–13; of posterior pair as 52–61–36–21–16. Calypters and halteres yellow, the former with very long, dense, black cilia, the hairs being as long as the face. Wings tinged with brown; costa filling in most of the space to first vein, this thickening ending before the tip of the first vein; anal angle very prominent.

Female: Face reaching a little below the lower edge of the eyes, rounded below. Antennæ, thorax, legs and feet about as in the male,

except that the middle tarsi are plain and the length of the tarsal joints vary somewhat. Cilia of the calypters long, but not unusually so, black. Wings with a very slight bordering of brown on the veins; costa a very little thickened before the tip of first vein.

Described from nine males and three females, taken on the Bright Angel Trail, Grand Canon, Arizona, and one female taken in Oak Creek Canon, Arizona, August, at an elevation of 6,000 feet; the last one was taken by F. H. Snow.

Type and allotype in the Canadian National Collection.

Polymedon nitidus new species.

Female: Length, 3.5 mm.; of wing the same. Face and front covered with silvery white pollen, the former extending about half its width below the eyes, rounded on lower margin. Palpi black, covered with white pollen and black hairs; proboscis with pale hairs. Antennæ yellow, third joint brown at tip, nearly round, but obtusely pointed at tip. Lateral and inferior orbital cilia white, a few of the upper ones black.

Thorax and abdomen green, shining, the latter with black hairs, the former on anterior half with gray pollen and black hairs.

Coxæ yellow. Middle and hind coxæ infuscated on outer surface of basal half; anterior pair with little black hairs on the front side and a row of about eight black bristles at tip. Femora and tibiæ wholly pale yellow; posterior pair with a bristle at apical third and minute pale hairs below; middle tibiæ with a bristle just beyond apical third on lower anterior edge; middle and hind tibiæ with large bristles above, the latter without bristles below, but with a row of rather long, black hairs below. Tarsi black from the tip of the first joint; fore and middle basitarsi with little spines below, the posterior ones with a rather long bristle near the base below. Joints of fore tarsi as 37–12–10–7–10; of middle pair as 42–25–15–13–9; those of posterior pair as 34–40–25–14–13. Calypters and halteres yellow, the former with black cilia.

Wings grayish; costa thick as before the tip of first vein as beyond; last section of fourth vein bent quite abruptly the length of the cross-vein beyond that vein, a little arched beyond the bend; anal angle prominent.

Described from one female, taken on the Bright Angel Trail, Grand Canon, Arizona.

Type in the Canadian National Collection.

Polymedon nigrifemoratus new species

Female: Length, 5 mm.; of wing the same. Face and front black with white pollen, the ground color showing through on the front, face extending a little below the eyes. Palpi small, brown with pale hairs. Antennæ black, first joint on lower half of apical half, second on inner

side below and a spot on third below, yellow; third joint nearly round; arista black at base, yellowish beyond its first joint. Lateral and inferior orbital cilia whitish, about five of the upper cilia on each side black.

Dorsum of thorax brown with green reflections, its pollen gray, more brown on central portion; pleuræ more black with white pollen. Abdomen green, covered with white pollen and black hair; propleuræ with a few pale hairs and one large black bristle above fore coxæ.

Coxæ and femora black with yellow tips and white pollen; fore coxæ with minute black hairs on anterior surface and eight bristles at tip. Middle femora with a small preapical bristle on each side; posterior pair with four large bristles on upper anterior edge, ending in the preapical bristle. Tibiæ yellow with their tips a little brown, all with large bristles above; fore tibiæ with a large bristle on lower posterior edge near the middle; middle ones with two large bristles below, one near the middle and one at apical fourth; posterior pair with a row of six hair-like bristles on lower surface. All tarsi infuscated from the tip of the first joint, but base of second joint more or less yellow; all joints with small bristles at tip, posterior basitarsus with a large bristle near the base below; anterior basitarsi with small spines below. Joints of fore tarsi as 42–13–11–9–13; of middle ones as 65–30–24–12–13; those of posterior pair as 51–50–38–19–16. Calypters and halteres yellow, the former with black cilia which appears reddish in certain lights.

Wings grayish; cross vein bordered with brown; first section of costa very slightly thickened; last section of fourth vein bent a little before its middle, considerably arched beyond this bend; anal angle prominent.

Described from one female, taken in Oak Creek Canon, Arizona, at an elevation of 6,000 feet, in August.

Type in the author's collection.

This was probably taken by F. H. Snow although his name is not on the label.

Polymedon castor Wheeler.

Females that Dr. Aldrich and I have determined as this species have one large black spine at tip of palpi, there is a blackish stripe densely covered with white pollen on lower posterior edge of all femora; the posterior femora have two large preapical bristles; middle tibiæ with three, posterior ones with four large bristles below; posterior basitarsi wholly black with a large bristle near the base below.

ANOTHER INSECT VECTOR OF THE GIANT THORN-HEADED WORM OF SWINE*

Xyloryctes satyrus Fabricius (Scarabaeidae)

Both Genus and Species New to the Host List of this Parasite.

By ROBERT D. GLASGOW.

It has been shown that certain meadow-inhabiting species of North American May beetles† may serve as intermediary hosts to the giant thorn-headed worm of swine, *Macracanthorhyncus hirudinaceus* (Pallas) Travassos. The eggs of this worm occur in the "droppings" of infested swine; and from the excreta of these animals are washed into the soil by rain. The eggs may then be swallowed by grubs of the beetles indicated, while feeding on the roots of grasses or of other plants. In the body of the grub the parasite passes through the so-called larval stage of its life cycle; and when this "larval" development is completed, the worm becomes encysted within the tissues of the insect host. The cysts of this parasite may remain quiescent within the body of the infested grub for considerable periods of time; and they may even persist through the transformation of the insect host, and probably may be transported from one field to another by the flight of the infested adult beetle. The worm finally reaches its definitive host and completes its development when a pig happens to eat a grub or a beetle that harbors the encysted parasite.

Therefore, land inhabited by grubs or visited by adults of the May beetle species cited above, affords a suitable habitat for the transmission of this parasite from pig to pig. In addition

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*Contribution from the Entomological Laboratories of the University of Illinois, Number 107.

The studies upon which this report is based were begun at the University of Illinois, and continued during the summer of 1926 at the New York State Agricultural Experiment Station at Geneva, New York. The writer is indebted to the officers of that institution, and particularly to Professor P. J. Parrott and Dr. Hugh Glasgow for the facilities provided which made the continuance of the work practicable at that time.

†*Phyllophaga* spp. (species undetermined, but thought by Dr. L. O. Howard most probably to be *P. fervida* Fabricius (*arcuata* Smith), Stiles, C. W., Bull. de la Soc. Zool. de France, vol. 16, pp. 240-242, 1891. *Phyllophaga rugosa* Melsheimer, Glasgow, R. D., Ann. Ent. Soc. of America, vol. 19, pp. 252-254, 1926.

to lands harboring these primarily meadow-inhabiting intermediary host species, the forest also must now be recognized as a particularly favorable habitat for the dissemination of the giant thorn-headed worm, since the writer has just recently found *Xyloryctes satyrus* Fabricius to be a suitable host for its "larval" development.

Not only may the larva of *Xyloryctes satyrus* harbor the cysts of the giant thorn-headed worm, but the cysts, established in larvæ fed upon material contaminated with eggs of the parasite, have been carried by the writer through the transformation of this insect host, and recovered from the adult beetle.

The accompanying figures show some of the cysts of the giant thorn-headed worm in a larva, and in an adult beetle of *Xyloryctes satyrus* from which portions of the body wall have been cut away. In another instance, four hundred and ten cysts were counted in a single *Xyloryctes* larva.

Xyloryctes satyrus is a forest inhabiting species; the larvæ are large, and they seem to possess a considerable degree of tolerance for rather heavy infestations of the giant thorn-headed worm; they are usually abundant wherever they occur; and their habits would seem to expose them both to contamination by eggs of the parasite, and to capture by foraging pigs. *Xyloryctes satyrus* appears therefore to be a particularly dangerous potential factor in the dissemination of this important intestinal parasite, among swine that may be pastured upon or have access to forest covered land.

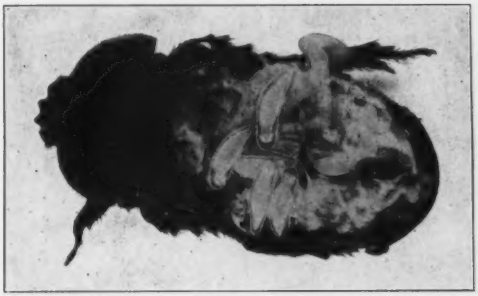


FIG. 1. Cysts of *M. hirudinaceus* in adults of *Xyloryctes satyrus*. Eleven cysts were taken from this particular beetle.

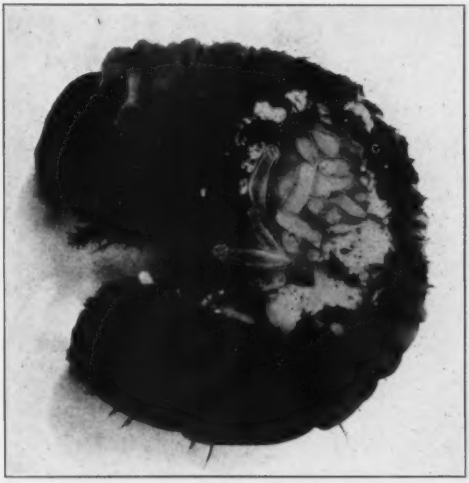


Fig. 2. Cysts of *M. hirudinaceus* in larva of *Xyloryctes satyrus*. Four hundred and ten cysts were counted in a single larva of this species.

PROCEEDINGS OF THE TWENTY-FIRST ANNUAL MEETING

PHILADELPHIA, PENNSLYVANIA, DECEMBER 27 AND 28, 1926.

The Twenty-first Annual Meeting of the Entomological Society of America was characterized by an unusually large attendance and interest. The attendance at the sessions ranged from 65 to 250, the average attendance for the five sessions being 133.

An outstanding feature of the meetings was a scholarly address on the subject, "Insect Parasites of Man", delivered at the evening public meeting by Prof. George H. F. Nuttall, of Cambridge, England. Another interesting part of the program was the symposium on "Needed Lines of Investigations in American Entomology." A number of interesting exhibits were prepared by members.

OPENING SESSION, TUESDAY MORNING, DECEMBER 27.

The Society was called to order at 10:00 A. M. by President William A. Riley, in Room 110, Logan Hall, University of Pennslyvania. Attendance 110. The following papers were presented; those starred by title only.

*1. Three New Species of Phytomyza (Agromyzidæ, Diptera). S. W. FROST, Arendtsville, Pa.
*2. A New Rabbit Brush Aphid from Utah. GEORGE F. KNOWLTON, Utah Agricultural Experiment Station.
3. The Variability of *Aphis gossypii*. C. H. BATCHELDER, University of Maine.
4. The Hippoboscid Fly, *Ornithomyia avicularia* Linn., as a Carrier of Mallophaga. H. E. EWING, U. S. National Museum.
*5. Embryonic Development in the Lepidoptera. O. A. JOHANNSEN, Cornell University.
6. The Development of the Castes of Bumblebees (Bremidæ, Hymenoptera). THEODORE H. FRISON, University of Illinois.
7. The Making of Microscopical Whole-Mounts of Insects. J. D. HOOD, University of Rochester.
8. Potentiometer Measurements of the Blood of Insects. DAVID E. FINK, U. S. Bureau of Entomology.
9. Remarks on the Distribution of Aquatic Hemiptera. H. B. HUNGERFORD, University of Kansas.
10. A Bibliography of Biographies of Entomologists. JOE S. WADE, U. S. Bureau of Entomology.
*11. The Biology and Immature Stages of the Sandflies (biting Ceratopogoninæ) at Puerto Castilla, Honduras. REGINALD H. PAINTER, Ohio State University.

The following Committees were appointed by the President:

Nominating Committee—J. S. HOUSER, (Chairman) E. O. ESSIG, P. W. CLAASSEN.
Resolutions Committee—H. B. HUNGERFORD, (Chairman) T. L. GUYTON, Z. P. METCALF.
Auditing Committee—J. M. ALDRICH, (Chairman) T. H. FRISON, D. M. DELONG.
International Congress Committee—P. P. CALVERT, (Chairman), E. D. BALL, F. E. LUTZ.

SECOND SESSION, TUESDAY AFTERNOON, DECEMBER 27.

The Society was called to order at 1:45 P. M. in Room 110, Logan Hall, University of Pennslyvania, by President Riley. Attendance 165. The following Symposium was presented:

"Needed Lines of Investigation in American Entomology"

Introduction, E. D. Ball.

1. In Taxonomy, S. A. ROHWER.
2. In Morphology, E. M. WALKER.
3. In Physiology, P. S. WELCH.
4. In Bionomics, R. W. DOANE.
5. In Ecology, W. C. ALLEE.
6. In Distribution, C. H. KENNEDY.
7. In Economic Entomology:
   (a) Needs in Study of Beneficial Insects, L. O. HOWARD.
   (b) Needs in Study of Insect Injuries, E. O. ESSIG.
   (c) Needs in Study of Control Measures, W. P. FLINT.

Summary, E. F. PHILLIPS.

THIRD SESSION, TUESDAY EVENING, DECEMBER 27.

The Society was called to order at 8:00 P. M. in the Lecture Hall, Philadelphia Academy of Science, by President Riley. Attendance 250.

The annual public address given at this session was made by Prof. George H. F. Nuttall, Cambridge, England, on the subject "Insect Parasites of Man."

The address was followed by a smoker in the Academy Building, tendered to all visiting entomologists by the local entomologists of Philadelphia.

FOURTH SESSION, WEDNESDAY MORNING, DECEMBER 28.

The Society was called to order at 10:15 A. M. in Room 110, Logan Hall, University of Pennslyvania, by President Riley. Attendance 75. The following papers were presented:

12. Do the Eupteryginæ Show Venation in the Basal Portion of the Elytra? D. M. DELONG, Ohio State University.
13. The Axillary Region of the Wing. WILLIAM T. M. FORBES, Cornell University.
14. Notes on the Biology and Habits of the Peruvian Cotton Square Weevil. W. E. HINDS, Louisiana State University.
15. A Method of Computing Mean Temperature for Biological Use. C. R. CUTRIGHT, Ohio Agricultural Experiment Station.
16. An Ecological Study of an Inland Salt Water Stream. P. W. CLAASSEN, Cornell University.
17. Insects of the Upper Air. E. P. FELT, New York State Museum.
18. Collecting Diptera in Guatemala. J. M. ALDRICH, U. S. National Museum.
19. Cold Hardiness in the Second and Third Instar of the Japanese Beetle (*Popillia japonica*). NELLIE M. PAYNE, University of Pennslyvania.
20. Orientation Reactions of Certain Whirligig Beetles. CARL R. BROWN and MELVILLE H. HATCH.

FIFTH SESSION, WEDNESDAY AFTERNOON, DECEMBER 28.

The Society was called to order a 1:45 P. M. by Vice-president Braun in Room 110, Logan Hall, University of Pennslyvania. Attendance 65. The following program was presented:

21. Factors in Phylogenetic Development. A. W. LINDSEY, Denison University.
22. The Olfactory Sense of Coleoptera. C. E. ABBOTT, Johns Hopkins University
23. A Preliminary Report on the Reponse of the Oriental Peach Moth and Codling Moth to Colored Lights. ALVAH PETERSON and G. J. HAEUSSLER, U. S. Bureau of Entomology.
24. The Ways of Wasps. H. T. Fernald, Massachusetts Agricultural College.
25. System in Scientific Names. E. P. FELT, New York State Museum.
26. A New Record Relative to the Parasites of *Pholus achemon* Drury. HAZEL E. BRANCH, University of Wichita.

The following excellent exhibits were on display in Room 212, Logan Hall, University of Pennslyvania, during the sessions:

1. *Diatraea saccharalis*—Sugar Cane Borer—Stages of Life History and Specimens of Work, by W. E. HINDS, Louisiana Agricultural Experiment Station.
2. *Anthonomus vestitus*—Peruvian Cotton Square Weevil, by W. E. HINDS, Louisiana Agricultural Experiment Station.
3. Specimens of Thysanoptera, showing Technique as Discussed in Paper on Program, by J. D. HOOD, University of Rochester.
4. An Electro-Gutzeil Apparatus for the Quantitative Estimation of Minute Amounts of Arsenic in Insects, by DAVID E. FINK, U. S. Bureau of Entomology.
5. Mounted Elytra of Eupteryginæ (Homoptera, Cicadellidæ), to show Venation, by D. M. DELONG, Ohio State University.
6. Japanese Beetle Exhibit, by LOREN B. SMITH, U. S. Bureau of Entomology.
7. Illustrations of Certain Phases of the Nomenclatural Situation, by E. P. FELT, New York State Museum.

The completion of the reading of papers was followed by the annual business meeting.

REPORT OF THE SECRETARY.

On March 24, 1926, the following, having been duly nominated and recommended, were elected members of the Society by mail ballot of the Executive Committee:

DWIGHT E. MINNICH, University of Minnesota, Minneapolis, Minn.
ROBERT W. DEVESON, Rochester, N. Y.
MARGARET HAIGH, Dearborn, Mich.
W. J. BROWN, Oklahoma Agricultural College, Stillwater, Oklahoma.
M. Y. MARSHALL, Mosley Hospital, Henderson, Ky.
ERNEST MORTENSEN, UVALDE, Tex.
C. O. DIRKS, Purdue University, Lafayette, Ind.
FRITZ CARPENTIER, Institute Ed. Van Beneden, Liege, Belgium.

By direction of the Executive Committee, Prof. Geo. H. F. Nuttall was invited to give the annual public address of the Society at the Philadelphia meeting. By mutual consent it was decided to hold a symposium on the subject, "Needed Lines of Investigation in American Entomology."

Dr. P. P. Calvert kindly consented to act as local representative for the Philadelphia meeting.

The Excutive Committee met at 5:00 P. M. December 28, 1926, in Logan Hall, University of Pennslyvania, with the following members present: W. A. Riley, Edith M. Patch, Annette F. Braun, J. A. G. Rehn, J. M. Swaine, Herbert Osborn, F. E. Lutz, and J. J. Davis.

The following members were elected:

HORACE FRANCIS BARNES, S. E. Agricultural College, Wye, Ashford, Kent, England.
RALPH D. BIRD, 203 Vivarium Bldg., Univ. Ill., Champaign, Ill.
E. P. BREAKLEY, 1539 Vermont St., Lawrence, Kansas.
W. H. BRITTAIN, Macdonald College, P. O., Quebec, Canada.
OSCAR L. CARTWRIGHT, Oswego, South Carolina.
FLOYD L. CLARKE, Newton, Utah.
CECIL N. DAVIS, 108 Whitten Hall, Columbia, Mo.
LORIN FIFE, 345 N. Third East, Logan, Utah.
PAUL B. FULLER, 1717 Third Ave., Evansville, Ind.
GEORGE HENDRICKSON, Dept. Entomology, Iowa St. College, Ames, Iowa.
H. G. JOHNSTON, Dept. Zoology, Iowa Agric. College, Ames, Iowa.
MOHAMMED KAMAL, Div. Ent., Ministry of Agriculture, Cairo, Egypt.
STEPHEN C. KLEENE, Amherst College, N. H.
WM. F. LAWLER, JR., 38 Murray St., New York, N. Y.
FRANK H. LETL, Sublette, Ill.
S. F. LIGHT, Dept. Zoology, Univ. California, Berkeley, Calif.
PAUL ROBERT NEEDHAM, Roberts Hall, Cornell Univ., Ithaca, N. Y.
U. S. L. PATE, 5703 N. 6th St., Philadelphia, Pa.
S. F. POTTS, 17 E. Highland Ave., Melrose Highlands, Mass.
WM. ROBINSON, Dept. Entomology, University Farm, St. Paul, Minn.
HERBERT H. SCHWARDT, Dept. Entomology, Kans. St. Agri. Col., Manhattan, Kans.
HERBERT FERLANDO SCHWARZ, Amer. Mus. Nat. His., 77th St. and Central Park West, New York, N. Y.
CHARLES J. SORENSON, Agric. Expt. Sta., Logan, Utah.
FRANK E. TODD, Bureau Plant Quarantine, Dept. Agric., Sacramento, Calif.
LAWRENCE ALBERT ZIMMER, 97 W. 9th Ave., Columbus, Ohio.

The following members have died during the year 1926:

E. T. CRESSON, SR.
E. A. HARTLEY
CHAS. W. MINOTT*
HENRY SKINNER
ANNIE T. SLOSSON

The following persons resigned during the year and their memberships terminated December 28, 1926:

C. I. BLISS
F. W. BOYD
E. K. BYNUM
E. R. DOWNING
J. EVENDEN
J. E. GUBERLET
R. H. HOWE, JR.
R. L. KING
C. W. LENG
M. E. MOSELY
F. B. PADDOCK
G. E. SANDERS
WM. SCHAUS
R. H. VAN ZWALUWENBURG
G. P. WELDON
A. B. WELLS
V. J. ZABROBSKY

A number of those resigned report that they requested their resignation a year ago which may account for the large number of resignations this year.

Total membership December 30, 1925 (See Annals XIX, p. 106)	689
Members lost by death	5
Members lost by resignation	17
Loss in membership during 1926	22
Balance	667
New members elected during 1925	33
Total present membership	700

*Died Nov. 28, 1925.

The following members were recommended for fellows in the Society: W. S. Blatchley, E. O. Essig and W. R. Thompson.

The following were elected members of the Thomas Say Foundation: E. C. Van Dyke and Nathan Banks, to succeed themselves.

The following were elected members of the Editorial Board of the Annals: J. A. G. Rehn, H. E. Ewing and R. W. Doane to succeed Wm. Schaus, E. C. Van Dyke, and W. E. Britton.

It was decided that no change be made in the investment of the permanent funds.

Respectively Submitted,

J. J. DAVIS, *Secretary.*

On motion, the Secretary's Report was accepted. The next item of business was the

REPORT OF THE TREASURER.

CURRENT FUNDS

RECEIPTS.

Balance, Dec. 30, 1925 (See Annals XIX, p. 107)	$1,912.55
From Annual Dues of Members	2,092.95
From Managing Editor of the Annals	975.75
From interest on bonds	47.42
From interest on deposit, April 1-July 1	20.00
Total	$5,048.67

EXPENDITURES

Express charges	5.56
Telegrams	.48
Refund on checks returned	12.00
Printing of 1925 programs	38.70
To H. Osborn for copies of Annals	2.00
Stamped envelopes	21.92
Stamps	42.11
Stenographic services, 1925	15.00
Stenographic services, 1926	66.90
Rubber Stamp	.84
Letter heads and notice cards	22.00
Lettering certificates	10.10
Envelopes for preliminary notices	3.50
Printing preliminary notices	10.00
Printing 1925 Annals	1,749.43
Total	$2,000.54
Balance, Cash on Hand, Purdue State Bank, Dec. 15	3,048.13
	$5,048.67

LIABILITIES.

The Society owes the publishers of the Annals for the March, June, September and December issues of the current year. We also owe $32.00 for printing of the programs and about $5.00 for clerical help.

PERMANENT FUND

The Society holds United States and Canadian Liberty Bonds totaling $1,100. as listed in the Annals, vol. XIX p. 108.

Respectively submitted,

J. J. DAVIS, *Treasurer.*

On motion the Treasurer's Report was accepted, subject to the approval of the Auditing Committee.

The report of the Auditing Committee was next called for:

The undersigned auditing committee have examined the books of Herbert Osborn, editor of the ANNALS, and of J. J. Davis, Secretary-Treasurer of the Society and Treasurer of the Thomas Say Foundation, and find the same to be correctly kept and balances on hand as reported by them.

(Signed) J. M. ALDRICH, *Chairman*,
T. H. FRISON,
D. M. DELONG.

President Riley then asked for the report of the Managing Editor of the Annals by Professor Osborn.

REPORT OF THE MANAGING EDITOR.

During the past year we have made progress in securing additional subscriptions and note with interest that the numbers going to foreign countries have been increased. The Annals now go to every state in the Union except one, Vermont, and to District of Columbia, Hawaii, Porto Rico and the Philippines.

The contents of the year have covered a wide range of entomological subjects and include a number of papers of broad biologic interest.

As in previous years, a number of authors have contributed toward the preparation of illustrations and in some cases, to part cost of the printing and we may note particularly, contributions from the Rockefeller Foundation for Medical Research and the Tropical Plant Research Foundation to provide for publication of articles and to the Colorado Experiment Station for the provision of colored plates, illustrating one of the articles.

A number of articles are in hand and we are assured of a good supply of material for the coming year.

I wish to thank the members of the Editorial Board for the support during the year and particularly to express obligation to Dr. C. H. Kennedy for his continued help in the management of the Journal.

The receipts and expenditures have amounted to $1299.20 and are summarized in the following statement:

RECEIPTS.

Non-member subscriptions (continuations)	$ 346.37
Non-member subscriptions (new)	48.80
From sale of back volumes and numbers	457.85
From payments on extra reprints	155.57
From payments on engravings	290.61
Total	$1,299.20

DISBURSEMENTS.

Postage and mailing account	$ 66.09
Engraving bills paid	219.84
Stenographic and clerical help	34.00
Miscellaneous expense	3.52
Balance remittances to Treasurer	975.75
Total	$1,299.20

HERBERT OSBORN, *Managing Editor.*

The report of the Treasurer of the Thomas Say Foundation was then called for.

REPORT OF THE TREASURER OF THE THOMAS SAY FOUNDATION
FOR THE YEAR 1926.

RECEIPTS

Balance on hand January 1, 1926	$ 65.02
Payments on Vol. 1, delivered previous to Jan. 1:	
2 @ $3.00 and 1 @ $2.55	8.55
Sale of vol 1:	
3 @ $3.00	9.00
3 @ $2.25	6.75
1 @ $3.14	3.14
Payments on vol. 2, delivered previous to Jan. 1:	
12 @ $5.00 and 1 @ $4.67	64.67
Sale of volume 2:	
8 @ $5.00	40.00
6 @ $4.50	27.00
1 @ $4.95	4.95
Loan to pay printing bill for volume 2	565.00
	$794.05

EXPENDITURES

Postage on volumes mailed	$ 5.74
Postage stamps	3.00
Interest on $150 @ 6% Oct. 1, 1925—Jan. 1, 1926	2.25
Interest on loan $565.00 Jan. 1, to July 1, 1926	16.95
Lafayette Printing Co., Balance due on vol. 2	652.23
Cash to reduce loan	65.00
Balance on hand	48.88
	$794.05

There is a balance due on loan to pay for printing volume 2 of $500.00

Respectfully Submitted,

J. J. DAVIS, *Treasurer.*

This report was accepted.

The Editor of the Thomas Say Foundation was called upon for a report. No publications were issued during the year and no report was therefore submitted by Editor Aldrich.

The President next called for the report of the Committee on Resolutions, which was as follows:

Your committee begs to present the following resolutions:

That the Entomological Society of America expresses its appreciation for the facilities placed at its disposal by the University of Pennslyvania through the personal efforts of Dr. P. P. Calvert.

That thanks be extended to the Philadelphia Academy of Natural Sciences and the Entomologists of Philadelphia and vicinity for their splendid hospitality.

That we acknowledge our gratitude to Dr. George H. F. Nuttall of the University of Cambridge for his excellent and instructive address given at the annual public meeting.

That the Society commends its officers for their efforts in providing a program of such general interest. We wish to call especial attention to the instructive character of the exhibits and to recommend that more emphasis be placed upon the display feature.

That the Entomological Society of America deeply regrets the illness of its first president, Prof. J. H. Comstock, who has done so much for this Society and to whose untiring efforts American Entomology owes a great debt of gratitude. That the Society expresses the sincere hope that he may soon recover.

Your committee suggests that the Secretary be instructed to send a copy of these resolutions to Professor and Mrs. Comstock.

Respectfully submitted,

(signed) H. B. HUNGERFORD, *Chairman.*
T. L. GUYTON,
Z. P. METCALF.

The Nominating Committee reported as follows:

The Nominating Committee presents for the approval of the Society the names of the following members:

For President—F. E. LUTZ
For First Vice-President—W. E. HINDS
For Second Vice-President—E. P. VAN DUZEE
For Secretary-Treasurer—J. J. DAVIS
For Additional Members of the Executive Committee—
For Term Expiring Dec. 31, 1929—W. A. RILEY and EDITH M. PATCH.
For Councillors to the American Association for the Advancement of Science—J. M. ALDRICH and C. L. METCALF.
For Committee on National Museum—HERBERT OSBORN, Chairman; C. W. JOHNSON, JAMES G. NEEDHAM, NATHAN BANKS, E. C. VAN DYKE.

Respectfully submitted,

(Signed) J. S. HOUSER, *Chairman,*
E. O. ESSIG,
P. W. CLAASSEN.

By vote of the Society the report was accepted and the Secretary instructed to cast the unanimous ballot of the Society for the election of the persons nominated. This being done they were declared elected.

President Riley next called for the report of the committee appointed to consider improvement of our program.

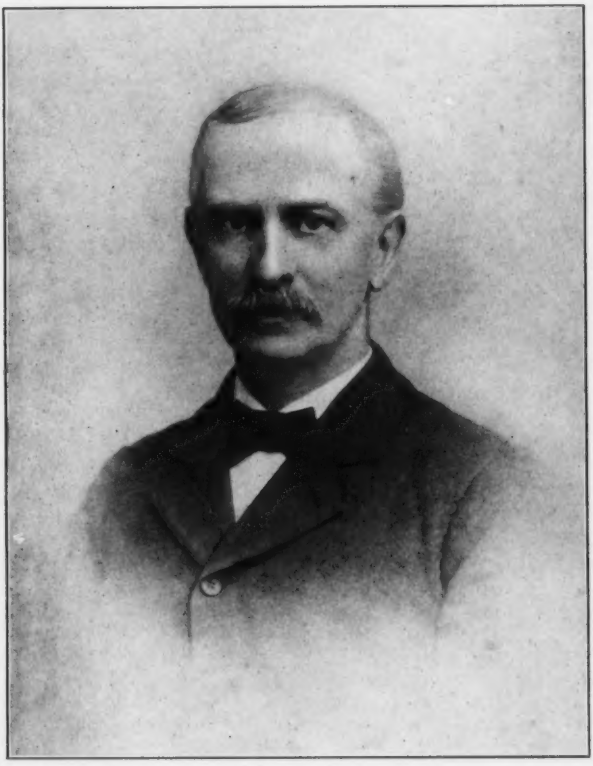
The report follows:

Your committee, appointed to study possibilities for the improvement of programs, working in cooperation with a similar committee of the American Association of Economic Entomologists begs leave to report as follows:

1. It is recommended that the program arrangements be left to the secretaries of the two societies as heretofore.
2. That the annual entomologist's dinner be scheduled as nearly as possible about the middle of the week for the convenience of those who may not wish to remain throughout the economic sessions.
3. It is suggested that consideration be given to holding the meeting at occassional intervals at some entomological center rather than at the scheduled meeting place of the American Association for the Advancement of Science. That this matter be left to the Executive Committees of the two Societies for further consideration and report.
4. It is further suggested that individuals or groups of individuals be requested to consult with the secretaries of the two societies before arranging for special interest meetings.

Respectfully submitted,

(Signed) J. J. DAVIS, *Chairman,*
J. M. ALDRICH,
HERBERT OSBORN.



EZRA TOWNSEND CRESSON (1895)

The special committee on the International Congress then reported as follows:

The Committee on the International Congress of Entomology recommends that the Entomological Society of America, in conjunction with the American Association of Economic Entomologists, invite the Permanent Committee of the Congresses to hold the Fourth International Congress at Ithaca, New York, between August 15 and September 15, 1928. This recommendation does not commit the Society to any expenditures on account of the Congress.

It is suggested that the Committee be continued, to act in conjunction with a corresponding committee of the American Association of Economic Entomologists to make necessary arrangements for the Congress.

Respectfully submitted,

(Signed) P. P. CALVERT, *Chairman*,
F. E. LUTZ,
E. D. BALL.

The special Committee, consisting of P. P. Calvert, Chairman, J. C. Bradley and R. C. Williams, Jr. reported as follows:

RESOLUTIONS ON THE DEATH OF E. T. CRESSON

In the death of Ezra Townsend Cresson, on April 19th, 1926, the Entomological Society of America has suffered the loss of a beloved Honorary Fellow. To those of us who knew him, his memory like an attending presence, will ever remain an inspiration toward the highest goals.

So modest and unassuming was the character of Mr. Cresson, that few of the present generation of entomologists knew him personally, and yet his name is known and honored in whatever part of the world entomology is studied.

We recognize the clear vision that perceived at the outset of his career the imperative necessity for an appropriate vehicle open to all American entomologists for the publication of their researches, and which led him to overcome every obstacle, even to setting the type for the early volumes with his own hands, to the establishment of an entomological serial, the first in the new world, which has not since been rivalled in scholarliness and importance, and which at once assumed and has since maintained a front rank among the learned publications of the world. For forty-two years he actively edited this series.

Not content, he appreciated the need for another serial of different function and was chairman of the committee that in 1889 determined upon the publication of the Entomological News.

At a time when economic entomology was scarcely existant, he edited the Practical Entomologist "for gratuitous distribution among farmers and agriculturalists."

Despite these unceasing labors on behalf of his fellow entomologists, gaining his living all the while as Secretary of an Insurance company, so great was his devotion to science, that he nevertheless produced a long series of monographs on the Hymenoptera, of great merit and distinction, that form for more than a foundation upon which all further studies of the North American Hymenoptera must be built. These labors gained him rank as one of the world's great entomologists of the 19th Century.

The Entomological Society of America can lay no higher tribute than to attest, by rising and unanimous vote, that he lived and accomplished, as they each and severally would live and accomplish, were they gifted with his powers, and were it given to them to realize their ideals.

(Signed) J. C. BRADLEY,
R. C. WILLIAMS, JR.
P. P. CALVERT.
Committee.

RESOLUTIONS ON THE DEATH OF DR. HENRY SKINNER.

Dr. Henry Skinner died on May 29, 1926, at the age of sixty-five. He was a charter member and fellow of the Entomological Society of America, elected 2nd. Vice-President at the first meeting, presided at the second meeting and was elected President in 1908.

He became interested in insects as a young man and the butterflies in particular, following Dr. Samuel H. Scudder and Mr. William H. Edwards and carrying on their work as the outstanding authority on the North American Rhopalocera between the older group and the present young generation of students, equally well beloved of both.

His contributions to scientific literature were large and valuable, his first paper appearing in 1882 and his "Synonymic Catalogue of the North American Rhopalocera" in 1898. He was Editor of Entomological News from 1890 to 1910, President of the American Entomological Society from 1916 to 1925 and Vice-President of the Academy of Natural Sciences in Philadelphia since 1918, where he was Curator of the Entomological Department and an indefatigable worker until his death. His genial and kindly personality, his helpfulness to visitors and correspondents especially the encourgement and assistance he gave to beginners not only endeared him to all, but materially added to the ranks of the working entomologists.

The Entomological Society of America wishes to place on record its appreciation of this great scientist and courteous gentleman, deeply beloved by a host of friends at home and abroad.

(Signed) R. C. WILLIAMS JR.,
J. C. BRADLEY,
P. P. CALVERT.
Committee.

Professor Herbert Osborn next presented the report of the Committee on National Museum.

REPORT OF COMMITTEE ON NATIONAL MUSEUM.

At the meeting of the Society last year, "it was moved and the motion carried, that this Committee be requested to include as a supplement to each annual report a record of important additions to the Canadian National Collection and to the entomological collections in the various states." In compliance with this request, the Committee has sent to a number of Institutions where important collections are maintained, requesting information concerning the collections. It was thought best since this was the first report to include such matter that "it might be in place for each one to indicate briefly the main characteristics of the collection, possibly some data as to content, relative numbers in different orders, presence of type material and availability for use of members of the Society." The replies to this request have been quite generous and the following extracts from the reports submitted contain, we believe, the information which will be of particular interest and value to our members. No attempt has been made to arrange these in order of importance, alphabetically or geographically.

National Museum, Washington, D. C.—"It gives me much pleasure to deposit in the United States National Museum, as a gift presented in loving appreciation and honor of Dr. E. A. Schwarz, my collection of water beetles of the families Dytiscidæ and Haliplidæ, consisting of about 20,000 specimens, representing approximately 400 North American and perhaps 200 additional exotic species, including a few of the Fall types and a large number of cotypes and paratypes of the Fall species. This collection is in many ways the counterpart of both the Roberts collection of these beetles in the American Museum of Natural History and of the Blanchard collection in the Museum of Comparative Zoology, so that all three institutions now have fairly complete collections of the North American species of the beetles. My earliest interest in entomology was carefully fostered by Dr. Schwarz, to whom I was "turned over" by Prof. C. V. Riley and Dr. Howard almost forty years ago, and my own collection is principally the result of Dr. Schwarz's encouraging and guiding hand both at the start and in the years following." JOHN D. SHERMAN, JR.

DR. HENRY SKINNER (1919)

From the National Musuem also it is reported that steel cases have been received for the permanent installation of the Casey Collection of beetles. Work on the labelling of the specimens has been progressing steadily, and a considerable portion of the collection is now in final form, through the interest and generosity of Mrs. Casey. Several visiting specialists, who have already examined some of these types, have expressed great pleasure in finding the collection so well taken care of. The Museum has recently received from Mr. Geo. M. Greene, Harrisburg, Penna., a collection of about 200 beetles, mostly from China and Japan.

Entomological Branch, Department of Agriculture.—The Canadian National Collection, has recently published an extended report upon the collections in the February, 1926, number of the Canadian Field Naturalist. The report is too extended to include here, but the following paragraph will indicate the extent of the collection.

"The National Collections of Insects is now contained in 31 steel cabinets of 1,550 drawers apportioned as follows: Lepidoptera, 625 drawers; Coleoptera, 250 drawers; Diptera, 225 drawers; Hymenoptera, 200 drawers; Hemiptera, 50 drawers; Orthoptera, 50 drawers; Odonata, 75 drawers; Ephemeridæ, 50 drawers; Neuropteroid insects (Partially unclassified), 25 drawers. There are besides two cabinets of alcohol material, including collections of Arachnida, Odonata and Ephemerida, and several slide-cabinets containing our material in plant-lice, fleas and thrips, etc."

"I might add that the chief addition this year to the collection besides the material coming in from our field officers, has been the collection made by myself in the vicinity of Lillcoet, B. C., amounting to 6,000—7,000 specimens. The number of species in the collection represented by type material at the present time is 2,358. Students of any order of insects are always welcome at Ottawa and are given every facility to carry on their research. In certain instances material is loaned to specialists working on monographic revisions."

J. McDUNNOUGH, *Chief.*

Museum Comparative Zoology, Cambridge, Mass.—The only large accessions in the past year were the Myers Salt Cuban Collection. The Curator's trip to Mt. Washington, and Dr. Wheeler's Morrocan Collection. The Collections include: *Arachnida*—Emerton types, Peckham Attidæ, Miss E. B. Bryant New England Coll., Chamberlain Coll., and Banks Coll. *Myriopoda*—Chamberlain Coll., Count Athems Coll. *Thysanura*—Packard Coll. *Neuroptera*—Hagen Coll., Banks Coll. (Over 2500 types, some over 100 years old). *Orthoptera*—Scudder Coll., Morse Coll. *Hemiptera*—No large collection. *Hymenoptera*—No large collection, but Osten Sacken, Cynipidæ, Dr. Wheeler's gifts of ants, and the Banks Psammocharidæ are notable. *Diptera*—Lower Coll., Osten Sacken Coll., (over 2000 types). *Lepidoptera*—Scudder butterflies, Treat Coll., Roland Thaxter Coll., Packard and Swett Geometridæ, Chambers and Dietz Microlepidoptera, and recently the bulk of the Jacob Collection (Presented by Mr. Cassino). *Coleoptera*—The Zimmerman Coll., Melsheimer and Ziegler Coll., the invaluable Leconte Coll. (with over 6000 types), the T. Blanchard Coll., Roland Hayward Coll., W. G. Dietz Coll., The Deyrolle Coll., of Rhynchephora and Cerambycidæ, The Harris Coll., of Cincindelidæ, the Bowditch duplicates in Chrysomelidæ (About 40 or 50 thousand specimens). Fossil insects—The famous Scudder Coll., and materials gathered by Dr. Hagen.

Much material was secured through expeditions, such as the Thayer Brazilian trip, the Uhler Hayti trip, the Thomas Barbour trip to the East Indies and elsewhere, the Mann trip to Solomon Islands and Fiji and Hassler expedition, and the Banks Panama trip. Insects have been obtained from many collectors, such as Wright in Cuba, Wright in Jamaica, Schwab in Kamerun, Boll in Texas and Kellerman in Guatemala, Goldsmith in Mexico, Steinbach in Bolivia, and hundreds of other lots.

The rooms are open every week-day, except in August, and the collections are available to any entomologist of standing; the Leconte collections only to specialists. Altogether there are types of over 19,000 species.

NATHAN BANKS, *Curator.*

New York State Museum, Albany, New York.—The New York State collection of insects comprises some 180,000 specimens representing all orders, the Lepidoptera and Coleoptera being especially well represented. We have probably the best collection in the world of Itonididæ (Cecidomyiidæ). There are approximately 1,000 types in the collections mostly of gall midges though there are a few in other groups. There is also a large amount of biological material. We have a number of small collections. The Fitch types described in his catalogue of insects collected and arranged for the State Cabinet of Natural History (Reprinted in the Ninth N. Y. Report). The Erastus Corning Collection of some 10,000 specimens. The J. A. Lintner collection. The last three are strong in Lepidoptera.

There have been no notable additions to our collections this season.

The Erastus Corning collection of Lepidoptera has been transferred to the custody of the New York State Museum by a recent vote of the Executive Committee of the Albany Institute and Historical and Art Society title of said collections however to remain with the Society. The Corning collection of Lepidoptera comprises somewhat over 4,000 specimens, the Sphingidæ, the Catocalas, and the Bombycidæ being particularly well represented. There are also a number of magnificent, exotic Lepidoptera, mostly Rhopalocera. This action places a magnificent collection where it will be given suitable care and morever brings under one roof the work of three early, enthuiastic entomologists, namely, Messrs. J. A. Lintner, W. W. Hill and Erastus Corning, all co-workers in the latter part of the last century. The Lintner collection is particularly strong in the Noctuidæ, though it contains many other forms collected by Dr. Lintner during the earlier years of his entomological activities. The Hill collection comprises some 10,000 specimens representing over 3,000 types, the Nymphalidæ, the Lycaenidæ, the Hesperidæ, the Sphingidæ and the Noctuidæ being particularly well represented. An account of this last collection and a list of the species is given in N. Y. State Museum Bulletin 124, pages 61 to 117, 1908.

E. P. FELT, *State Entomologist.*

The Academy of Natural Sciences of Philadelphia, Philadelphia, Pa.—The collection of Lepidoptera includes the Skinner Collection of North American Rhopalocera with approximately 100 types, the Martindael collection of Exotic Lepidoptera and also many of the types of Grote, Blake, Mengel and others. In the Hymenoptera will be found almost all the types of Mr. E. T. Cresson, numbering about 2,600, many of those of Fox, Blake, Viereck and others, including the Bassett Collection of Cynipidæ.

The collection of Coleoptera includes that of Dr. George H. Horn with more than 67,000 specimens and over 1,500 types and also the Wilt Collection. In Orthoptera the collection includes around 500 types and the Hebard Collection, on deposit at the Academy, 1,086 types. In Odonata is included the important Calvert Collection. The collection of Diptera is large and particularly the Ephidridæ, in which Mr. E. T. Cresson, Jr., is specializing, includes many types. Large collections of most of the others are present but in many cases are largely unstudied.

During the present year, the R. C. Williams, Jr. Collection of Neo-Tropic Hesperidæ, including about 400 species and 2,500 specimens, is being included in the Academy Collection; and Dr. W. G. Dietz' collection of Tipulidæ has recently been presented to this institution. The growth of the collections is at present vigorous in the following orders in which active studies are being pursued by the following individuals; Lepidoptera (Rhopalocera) by R. C. Williams, Jr. and W. J. Coxey, Diptera by E. T. Cresson, Jr. and Orthoptera by J. A. G. Rehn and Mr. Hebard.

MORGAN HEBARD, *Curator of Insects.*

University of Minnesota, St. Paul, Minn.—The insect collection here numbers about 400,000 to 500,000 specimens. The collection was established by Prof. Otto Lugger in the early days of the department and his collection still remains intact. It is especially rich in Coleoptera, practically all of which are determined. The Lugger collection is representative of the United States as a whole and includes many exotic forms. During the last twenty years many additions have been made to the collection and at the present time the orders Orthoptera, Hemiptera and Coleoptera are well represented with indentified material. The collection

contains the types of a number of Mutillidæ and considerable paratype material in the Miridæ. There is an abundance of unidentified material in the remaining orders. There have been no notable additions to the collection during the past year.

CLARENCE E. MICKEL, *Professor Entomology.*

Michigan State College, East Lansing, Mich.—Our collection here at the college occupies a special fire-proof building located near the laboratory and entirely accessible. It fills about 700 Harvard cases of which the contents of 600 are arranged and 100 merely named, but not worked into series. Besides these, we have of course, a lot of accessions, material not yet identified. We estimate the collection to contain between 25 and 30,000 species with the greatest numbers in Coleoptera and Lepidoptera. There are types here and there throughout the series, but no very great number. There are, however, many insects belonging originally to the Tepper collection and a good many insects determined by the older entomologists such as Cook, Riley, Leconte, Horn, etc.

We are always glad to allow specialists to compare material with our collection, but in the past the collection has suffered quite a bit from having material shipped abroad for examination.

R. H. PETTITT, *Professor Entomology.*

University of Illinois, Urbana, Ill.—The insect material at Urbana, Illinois, available for the use of members of the Entomological Society of American belongs to three independent units. There are the Illinois State Natural History Survey, the Natural History Museum of the University of Illinois, and the Dept. of Entomology of the University of Illinois. These collections are available to members of the Survey Staff for study, in keeping with the cooperative policy which also places the facilities and insect collection of the Survey at the service of the University.

The most important collection of insects is in the possession of the Illinois State Natural History Survey. This collection contains a few specimens dating back to the periods of William LeBaron (1870-1875) and Cyrus Thomas (1875-1882). However, to Stephen Alfred Forbes belongs the honor of really starting a collection of the insects of the state. The present collection, then, consists almost entirely of specimens collected since 1883. As a result of wise policy of many years accumulation and direct collection of insect material, the survey now possesses the most complete collection of Illinois insects in existence. The scope of the collection has never been definitely defined, but it's particular objective is to have a complete collection of the adult and immature insects of Illinois. No special attempt is made to secure exotics, but donations and exchanges of North American species are desired. The collection contains approximately 400,000 specimens, pinned insects, about 5,000 slides and 30,000 vials and bottles of material preserved in alcohol. The types in the collection are approximately as follows: 400 holotypes, 150 allotypes and 2,000 paratypes.

In addition to the material acquired by direct collecting, several collections of varying size have been acquired by purchase and incorporated with the collection of the Survey. The most notable of these is the first collection of Dr. W. A. Nason, acquired in the year 1908. Another collection of insects was obtained from the first president of the University of Illinois, S. H. Peabody, in 1891.

A complete list of the insect types in the Survey collection and a brief sketch of the latters origin and development is now in press. This will be sent to entomological workers on request.

The Natural History Museum of the University of Illinois possesses the Andreas Bolter and the second W. A. Nason collections of insects. Both of these collections were gifts to the University, the former in 1900 and the latter 1920. The Bolter collection contains a few types and about 120,000 pinned specimens from all parts of the world. The series of Coleoptera is particularly good. The second Nason collection contains about 25,000 miscellaneous pinned specimens and no types.

The Department of Entomology of the University of Illinois acquired the A. D. MacGillivray collection of Tenthredinoidea in 1924. This is one of the most important collections of saw-flies in North America and contains about 5,000 specimens and 400 holotypes. This collection is housed with the types of the Natural History Survey.

Practically all types stated *in litt.* to date to be in the collection of the University of Illinois or the University Museum should be credited to the Illinois State Natural History Survey. The latter organization was created by law, in 1917, by the merger of the State Laboratory of Natural History and the Office of the State Entomologist. Therefore, all types stated *in litt.* to be in the possession of the State Laboratory or Office of the State Entomologist are now in the Survey collection.

No especially notable additions were secured during the past year. Of course many specimens were received in exchange and by donations, including paratypes, but nothing that I would designate as "notable". Many thousand additional specimens were added by collecting in various parts of the state.

THEODORE H. FRISON.

Bureau of Plant Industry, Pennslyvania—The collection began about twenty-five years ago. At present it contains about fifty thousand specimens, and from eight to ten thousand species. Incorporated with this collection are the Daecke collection which is especially rich in Diptera; certain families of the Champlain and Kirk collections notably the Carabidæ; hemiptera and other material donated by Mr. J. G. Sanders; Florida specimens donated by Messrs. Knull and DeLong, and considerable western material donated by various collectors.

The Pennslyvania material has been collected by many workers who at one time or other have been connected with this Bureau, and has been identified by specialists in the various groups. A large part of the type material belonging to this collection was recently deposited with the U. S. National Museum. It is the policy of those in charge of this collection that all such valuable specimens should be deposited with that collection. The collection is always open for the use of any member of the Society or anyone else who is capable of appreciating its character, and making proper use of it.

T. L. GUYTON, *Chief Entomologist.*

Boston Society of Natural History, Boston, Mass.—The Society's collections are now strictly New England and the collection of insects contains about 8,500 determined species (over 50,000 specimens including some 550 types). Aside from this is the Harris collection (one of the oldest in this county) which contains about 5,000 species and 150 types.

C. W. JOHNSON.

Kansas State Agricultural College, Manhattan, Kan.—This department does maintain a good, strong, growing collection of insects. It has been kept in Schmitt boxes, but last year we adopted the tray system, as used by the U. S. National Museum. As fast as possible, we are transferring all determined material to the trays. We have three cabinets holding respectively 100,600 and 48,000 drawers of trays. We have adopted the U. S. National Museum sizes of trays, of which there are four, and their type of drawers. We will use the Schmitt boxes for duplicates and undetermined material.

The first contributions to the collection were made by Prof. A. E. Popenoe, head of the department of entomology from 1879 to 1908. In 1902 Prof. G. A. Dean, now head of the department began adding to the collection. Probably more specimens in the collection were given by him than by any other contributor.

The most important additions to our collection during the year were from collections made by Prof. J. W. McColloch on a trip to the sand dunes at Medora, Kansas, in July, and by Prof. McColloch and the writer on a trip to western Kansas and eastern Colorado in August. We attended the Pingree Park Conference. Of course, there is an annual accretion of several hundred specimens from collections made by students.

The collection includes about 3,500 species determined by specialists.

We have very little type material. There are several types in the Hymenoptera, but it is our policy to deposit types in the U. S. National Musuem. We have probably two dozen or more paratypes.

We are glad to have any person who is interested in the study of any group come here and use the collection. We have also been liberal in sending specimens to specialists for determination and study. We prefer not to send determined

material and specimens already arranged in the Schmitt boxes or trays. It requires a great deal of extra labor and endangers specimens which we feel are very valuable.

I might stress the importance of the donation of the Knaus collection of Coleoptera. He is now arranging them in Schmitt boxes. When they are all arranged and determined, they are to be sent to this institution and the collections will be kept in fire-proof cabinets. The collection has already been formally accepted by the Board of Regents.

ROGER C. SMITH, *Professor of Entomology.*

Field Museum, Chicago, Ill.—Lepidoptera (Strecker Coll.)—This collection was made by Herman Strecker, Reading, Pennslyvania, and was purchased by the Museum in Sept. 1908. It consists of 24,166 butterflies and 22,546 moths (but no micros), as well as nearly 4,000 duplicates. In addition to the many rare species and abberations, it contains 251 types and paratypes representing 435 specimens described by Strecker, and Reakirt, Behr and others. The collection is still in the drawers and cabinets used by Strecker. *Lepidoptera* (A. J. Snyder Coll.)—A purchase made in June, 1904, and consisting of 5,564 butterflies and moths of North America and 409 exotic specimens. The collection contains a large series of Argynnids, in which Prof. Snyder was much interested, and a good series of Catocalas. About half of this collection has been transferred to better drawers, but the other half is still in the original drawers and cabinet. *Lepidoptera* (August Salla Coll.)—A gift received November, 1917, and consisting of 2,000 North American butterflies and moths, and several hundred beetles. The beetles are in their original glass topped drawers, and have very little data. *Lepidoptera* (J. G. Sorup Coll.)—A World's Fair collection which was purchased when the Museum was started and which has been on exhibition ever since. It consisted of about 3,000 specimens, now faded, of butterflies and moths of the world, but with practically no data. *Lepidoptera and Coleoptera* (George F. Curtis Coll.)—A donation received in March, 1914, and consisting of 16—specimens of butterflies, moths, and beetles, most of which are in poor condition and with very little data. *Coleoptera* (E. B. Chope Coll.)—This collection, purchased in August 1906, contains 10,819 specimens, representing 3,028 species, of North American beetles. Specimens have merely state labels and are still in their original boxes. *Coleoptera* (George P. Wells Coll.)—A donation received in Dec. 1900, and comprising about 6,000 North American beetles, most of which are without even state labels. It is preserved in the original book boxes. *Diptera* (Dr. Garry de N. Hough Coll.)—A twenty-year deposit made in December, 1920, by the University of Chicago. This collection of flies consists of close to 5,000 specimens, and is of considerable value in that it contains about seventy-five (when purchased by the University there were more) types of Anthomyidæ described by P. Stein, and also a few types of species named by Dr. Hough and Prof. Melander.

The acquisitions this year have been of the usual kind, varying from one specimen to three hundred and not being of any noteworthy interest. Mention, however, might be made of a gift from Dr. Lewis H. Weld of 221 galls and gall flies, of which all but thirteen are paratypes.

WM. J. GERHARD.

Massachusetts Agricultural College Department of Entomology, Our collections are, naturally, largely of New England material but with many specimens, particuarlly those of economic importance, from other parts of the country as well. As rapidly as we have been able to obtain and arrange them, all stages in the life history of the insect are added as an integral part of the collection and we have, protected in metal cabinets, about 1,000 specimens of types of varying rank, from holotype and allotype down to homotype. The main collection being necessarily, at a college like this, one which must be offered for general public examination at times, is kept in glass-topped trays and consists mainly of only two or three specimens of the adults, in addition to the early stages referred to. The remainder of the collection, however, is kept in part in trays and in part in Schmidt boxes, and there the material is, to quite an extent, in series showing variation, geographical distribution, etc.

Unfortunately, in too many of the groups, we have much unworked material, and we greatly need a curator, but we have thus far found it impossible to obtain permission from the State to engage one. We do a little something each year, however, in spare time, in the way of arranging, amplifying and improving. It would be impossible to give anything more than an estimate of the number of specimens in the collection, but I would make a guess that we have between 150 and 200,000 specimens. I nearly forgot to mention that we have quite a little material in the line of work of insects; e. g., work of bark beetles and such things, which, not lending itself to observation in trays, is kept for quite a part, in a museum case on shelves.

I do not think our collection is anything wonderful in any way, nor would it rate with the larger collections in the country by any means, but we do find it of a great deal of use with our students, and particularly certain trays, the material in which is brought together according to subject matter. Thus we have trays of the insects attacking vegetables, insects injurious to fruits, insects injurious in greenhouses, etc. These are in addition to the others previously referred to.

H. T. FERNALD.

Entomological Museum, University of Kansas, Lawrence, 1926—The entomological collections of the University of Kansas were started at the time of the foundation of the institution. This was due to the enthusiastic endeavors of Doctor Francis Huntington Snow, who in later years became Chancellor of the University. Doctor Snow, conducted many expeditions for the purpose of adding material to our entomological museum. With the Francis Huntington Snow collections as a nucleus the collection has been growing steadily to the present time. It now contains the following: North American Coleoptera, 9,000 species, 36,000 specimens; Lepidoptera, 3,756 species, 12,208 specimens, Diptera, 3,000 species, 7,845 specimens; Hymenoptera, 1,520 species, 4,000 specimens; Hemiptera, 900 species, 7,000 specimens; Homoptera, 725 species, 5,699 specimens; Orthoptera, 550 species, 2,000 specimens; Neuroptera, 350 species, 1,500 specimens; Coleoptera, 2,900 species, 8,500 specimens; Lepidoptera, 981 species, 1,716 specimens; Hemiptera, 5,000 specimens; Homoptera, 1,000 specimens; Duplicate collections for study, 250,000 specimens.

In addition to the above we have the following type material;

Neuroptera, 1; Orthoptera, 15; Hemiptera, 101; Homoptera, 85; Coleoptera, 14; Diptera, 582; Lepidoptera, 100; Hymenoptera, 276; African Diptera, 25; Coleoptera foreign, 14; Total, 1,223. The types include species described by Drs. Williston, Aldrich, Townsend, Snow, Cresson, F. X. Williams, Viereck, Lawson, and Hungerford, and Messrs. Curran, Robinson, Beamer and others.

H. B. HUNGERFORD.

The University of Nebraska, Lincoln, Nebr.—I warmly approve of the plan of recording annually the more important additions to the entomological collections of the various states, and will be glad to furnish the necessary information concerning the University of Nebraska collection.

This collection occupies an entire large room (208) in the fire-proof Plant Industry Building on the College of Agriculture Campus of the University of Nebraska, and the specimens are housed in mahogany drawers in steel cabinets identical with those in use in the U. S. National Museum. The collection contains approximately 400,000 specimens, and is particularly rich in exotic grasshoppers, crickets, mantids, walking-sticks, cockroaches and other *Orthoptera* (sens. lat.) assembled by Professor Bruner, as well as rich in North American Diptera and Hymenoptera, and in many families of the Coleoptera. Bruner's types of exotic *Orthoptera*: Williams' types of *Aphididæ*; Hunter's, Swenk's, H. S. Smith's and C. E. Michel's types of *Aculeate Hymenoptera* are well represented in the collection, which also has numerous types of sawflies described by Davis. Professor Bruner's collections of Mexican, Argentine and Philippine insects are also extensive, but largely unnamed. The collection is open for study by any responsible entomologist. During the past year there have been no outstanding additions to this collection.

MYRON H. SWENK.

Mississippi Agricultural and Mechanical College, A. & M. College, Miss.—In regard to our collection here at the Mississippi A. & M. College, there is not very much to report. As you know, our collection is chiefly a Mississippi collection. We have never made much effort to increase our collection of material from outside the state. There are a few groups in which special effort has been made to build up complete collections of Mississippi forms. I might mention especially the *Phyllophaga* (*Lachnosterna*), *Coccidæ*, *Cicadidæ*, *and Ipidæ*. So far as possible, we will be glad to send material to anyone who is interested in anything that we have here. R. W. HARNED.

The Connecticut Agricultural Experiment Station reports collections, mainly of Connecticut, with a total of over 6,000 species represented and including 131 types, 32 Conn. paratypes, and 25 paratypes not Connecticut and 6 co-types, the majority of these being in Hymenoptera.

Iowa State College, Ames, Iowa—The following additions have been made to the Iowa State Collection.

Faaborg Collection Lepidoptera purchased from Mr. J. S. Faaborg, Clinton, Iowa. Containing approximately 20,000 specimens and representing about 5,000 species; chiefly Nearctic and Palearctic forms but contains many from other regions. Collection of Miridæ presented to the Iowa State College by Dr. Harry H. Knight. Representing 353 species of which 268 are new additions to the Iowa State College collection and 143 species representing paratype material containing over 100 specimens and paratypes of all species of water-striders described by Drake. Collection of 100 species of Diptera from Dr. C. L. Fluke, Madison, Wisconsin. The collection contains a great number of Syrphidæ and has been determined by Dr. Fluke. The collection includes material which was assembled by Herbert Osborn for the college and C. P. Gillette, when he was Entomologist for the Experiment Station, and includes a series of types of Van Duzee Homoptera and the co-types of species described by Osborn and Ball. It is fairly complete for the Lepidoptera, Coleoptera, Hemiptera and Orthoptera for the state and includes some material from other localities. C. J. DRAKE.

Cornell University Insect Collection—The insect collections of Cornell University occupy over 3,000 cases 19 x 16 inches. Without having counted one may roughly estimate that they consist of somewhere between one and two million specimens. We have no count of the number of species represented in each order, but the relative size of the collection of each may be approximated from the number of cases devoted to it: Lepidoptera 800, Hymenoptera 580, Coleoptera 520, Diptera 300, Hemiptera 280, Odonata 170, Orthoptera 70, Neuroptera 50, Neuropteroid etc., 40, Trichoptera 25. The above estimates do not include the collection of Arachnida, which must rank as one of the two or three most extensive in this country. It is contained in what is estimated to be, between 20,000 and 25,000 vials. The collection is not limited to any geographical area, but particular emphasis is naturally laid upon the acquisition of the fauna primarily of New York State and secondarily of North American.

Out side of New York state material, besides innumerable lesser accessions from all parts of the world one may especially mention the following as sources of material each probably upwards of 25,000 specimens: Cornell University Entomological Expedition to South America of 1919-20, (100,000—200,000 specimens), Okefinokee Expedition of 1912-13, and other Ga., and Fla., material collected by J. C. Bradley during several years; British Columbia and Alberta material from J. C. Bradley 1905-1908; California material from J. C. Bradley 1906-07, 1914, 1915, 1917-19; Southern and Southwestern material from Cornell Biological Expedition of 1919; Heidemann collection of Hemiptera; R. J. Crew collection of Coleoptera. Of lesser extent, may be mentioned the Murtfeldt collection of Microlepidoptera, Sherman collection of Carabidæ, (640sp.) and extensive series of Hymenoptera from the Naturhistorische Museum of Vienna, 667 species of French spiders from Simon collection, about 1,200 species of exotic Hemiptera, (purchased), 730 species of N. A. Lepidoptera and Hemiptera from all regions from the Baker collection, collections of Chilean insects chiefly Hymenoptera from Alfredo Faz and from the Museo de Historia Natural of Santiago, of Argentinian from Carlos Read, of

Uruguayan insects from the Museo de Historia Natural de Montevideo. South America Hemiptera and Hymenoptera from H. L. Parish, East African Hymenoptera from H. Junod, an extensive Brazilean collection in all orders from A. G. Hammar; the sawfly collection accumulated previous to 1911 by the late A. D. MacGillivray, several thousand species of European insects of several orders purchased from time to time of Schniedeknecht, Konow, and from dealers. There have just been added about 250 determined and many undetermined Ithomiidæ and Danaidæ representing the personal collection of Fassl. Types of about 1,000 species have been catalogued, but the work is not yet completed. Every effort is made to make the collections available to persons engaged in scientific research, and members of the Entomological Society of America will be at all times welcome to make use of the collections. J. CHESTER BRADLY, *Curator.*

American Museum of Natural History—We have about 3200 species represented by type material. It is impossible to say how many other species we have but they are represented by about 1,000,000 specimens of which possibly 70% are identified either correctly or otherwise. They come from all parts of the world. All material is available for the study here by any member of the society but we do not loan types without the consent of the describer of the species.
FRANK E. LUTZ.

North Carolina State College—The college collection of insects consists chiefly of a collection of native and foreign Homoptera which is being arranged especially to show morphological relationships and is accompanied by a nearly completed index to the literature of the Homoptera of the world, now about 200,000 separate references to the genera and species. There is also a small general collection of the insects of all orders of North Carolina. Z. P. METCALF.

North Carolina Dept. of Agriculture—The Insect Collection of the Division of Entomology N. C. Dept. of Agriculture, is confined to North Carolina insects of all orders and their allies contains about 5,000 of the 7,500 species on record from the state and is contained in 750 Schmidt boxes. All the principal orders and most of the smaller ones are well represented in the collection.
C. S. BRIMLEY.

The collections of the Ohio State University include some quite extensive series of Lepidoptera and Odonata assembled by Dr. D. S. Kellicott. The Tallant collection of Lepidoptera, collections of Coleoptera and Orthoptera which are quite full for Ohio and extensive series of Diptera and Hemiptera which are largely the accumulations of material secured by Prof's. Hine and Osborn and the students who have worked with them.

(Signed) HERBERT OSBORN, Chairman,
C. W. JOHNSON,
WM. M. WHEELER,
JAS. G. NEEDHAM
Committee.

On motion it was moved that the report be printed in full. Motion carried.

After some discussion it was moved, seconded and carried that "a committee be appointed by the president to address a communication to the International Zoological Congress, expressing the views of the Society on certain questions in nomenclature; that this communication be based on a referendum to members of this Society." Committee appointed by newly elected president, Doctor Lutz, as follows: J. C. Bradley, Chairman, J. M. Aldrich and J. M. Swaine.

The meeting then adjourned.

Respectively submitted,

J. J. DAVIS, *Secretary.*